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# **Climate Change and Human Health: An Ecological study on climate variability and malnutrition in Fiji.**

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A thesis submitted in partial fulfillment of the requirements for the  
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## Dedication

I would like to dedicate this thesis to my Wife Ivamere Dali Cavuilati for her unwavering support and prayers in the two years that I have been away from home. Thank you for being a strong woman and single-handedly being a father and mother to our children in my two years of academic work. This thesis is for you and our children;

- Jese Rokalevulevu Vatukela
- Emily Sokoiwasa
- Mere. D. Tikomaisuva

Once again thank you so much and may God bless us all.

Maleka Vakalevu

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## Summary

Climate change has a significant effect on human health manifested by the increasing number of cases of climate-sensitive diseases. Europe and North America have experienced increasing number of deaths from heat waves, while in the Pacific there have been frequent outbreaks of dengue, leptospirosis, diarrhoea and typhoid. Climate change manifestation through extreme weather events have caused substantial loss of infrastructure and also the agricultural sector in Fiji which has increased the risk of malnutrition in the country.

This study aims to examine the relationship between climate variability and the prevalence of malnutrition in Fiji between January 2006 and December 2016. The study also examines the specific aspects of climate variability and malnutrition during the same period. The ecological study design was used as aggregated data on climate change were used in the study. The study conducted complementary quantitative and qualitative analyses. The quantitative part of the study was based on time series analysis, the additive model and smoothed using the moving average to determine the trend of climate, malnutrition and crop production. The qualitative aspect examined works of existing works of literature on the other factors associated with malnutrition to explain the malnutrition trend where there is no influence of climate variables.

The study found evidence of seasonality in the climate variables, but there was no statistically significant fluctuations in the trends of minimum and maximum temperatures and humidity. However, there were fluctuations shown in average total rainfall. High rainfall periods in 2012 coincided with an active La Nina and episodes of floods. The general trend of total rainfall shows that Fiji is getting drier.

There was seasonality found in child malnutrition where there was an increase in cases during the wet and hot summer season (November-April) and decrease in cases in the cold, dry winter season (May-September). The trend showed the prevalence of the indicators of malnutrition (underweight, growth faltering, severe malnutrition and anaemia) decreased in the first half of 2011 increased from the middle of 2011 to its highest peak in the first quarter of 2012 and decreased from the third quarter of 2012 until 2013. The decrease in malnutrition trend in 2011 was possibly due to the active government policies introduced such as the food voucher program, provision of the employment centre, the introduction of regulating infant food and promotion of breastfeeding. On the other hand, when the government introduced other policies such as the increase in value-added tax, it increased basic food prices, and it was difficult for needy families to get decent healthy meals. The extreme weather events (episodes of flooding) caused by La Nina and a tropical disturbance in the first quarter of 2012 exacerbated the prevalence of malnutrition. There were shortages of crops, fruits and vegetables and food prices increased. The malnutrition trend improved in the third quarter of 2012 and going into 2013 due to the resilience of the Fijian government and people in adapting to climate change. The government work in partnership with all its relevant stakeholders to minimise further health effects, through food, medicine, water rations and the supply of seedling and land preparation to affected farmers. The increase in the budget for water, food voucher and the introduction of other social protection policies and health policies implemented in 2010 may have reduced malnutrition further.

The effects of climate change such as episodes of flooding exacerbate the prevalence of malnutrition in Fiji. Climate change, through the increase in the intensity and the frequency of extreme weather events will be more severe in the future, but effective government policies and programs contribute to adaptation and resilience in minimising the effect. The findings of this study suggest that proactive policies from the Government may contribute towards building resilience against adverse effects of climate change in Fiji.

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## Glossary

- Albedo - is the measure of reflectivity of the incoming solar radiation on the earth surface. Ice with snow on it has a high albedo.
- Anaemia - it happens when there is lack of iron in the blood and in children it occurs when their is poor iron dietary intake or loss of iron from the body.
- Anthropogenic climate change - climate change that is entirely influenced by humans, it includes the excessive emission of greenhouse gases into the atmosphere through burning of fossil fuels through manufacturing, transport and agriculture.
- Eccentricity - it is a measure of how an orbit deviates from its normal path
- El Nino - it is a weather phenomenon that happens when the southeasterly trade winds weaken causing the warm waters of the western Pacific to flow eastwards. It causes more than normal rainfall in the eastern Pacific and the coast of South America and also causes less than average rainfall in the western Pacific.
- El Nino Southern Oscillation (ENSO) - a natural phenomenon in the tropical eastern Pacific where there is irregular variation in the winds and the sea surface temperatures. It influences weather in the tropics and the sub tropics.
- Fiji Indians - the descendent's of indentured laborers from India who were brought in during the Colonial system to work in the sugarcane farms.
- Growth faltering - it occurs when the infants growth slower than the expected growth rate on the defined infants growth curve and sometimes defined by the measurement of changes in normal weight gain.
- I - Taukei - the Indigenous people of Fiji. They are referred to as the I-Taukei in this thesis
- Inter annual - measured on a yearly basis or from one year to the next
- Intergovernmental Panel on Climate Change (IPCC) - it is a United Nations international body for assessing climate change. It carries out assessment of research conducted on climate change and produces a assessment report every 5 to 7 years.
- Intra annual - a process that occurs within a time frame of more than one month but less than one year
- La Nina- it is the opposite of El Nino when the southeasterly trade winds get stronger and push the warm waters further to the western Pacific. It causes wetter than normal conditions in the central and the western Pacific and drier than normal conditions witnessed in South America.
- Malnutrition - the various forms of poor nutrition. Underweight, stunting, wasting and micro-nutrient deficiency are other forms of malnutrition.
- Mate ni kana vakaca - An I Taukei term to describe a person suffering from any form of malnutrition.

## Abbreviations

- ABM - Australian Bureau of Meteorology
- ADB - Asian Development Bank
- BFHI - Baby Friendly Hospital Initiative
- CFC - Chlorofluorocarbons
- CSIRO - Commonwealth Scientific and Industrial Research Organisation
- ENSO - El Nino Southern Oscillation
- EPI - Expansion Program of Immunisation
- FAO - Food and Agriculture Organisation
- FSC - Fiji Sugar Cooperation
- IMCI - Integrated Management of Childhood illness
- IPCC - Intergovernmental Panel on Climate Change
- ITCZ - Inter tropical Convergence Zone
- MAM - Moderate Acute Malnutrition
- MCH - Maternal Child Health
- MDG's - Millennium Development Goals
- MJO - Madden Julian Oscillation
- MOHMS- Ministry of Health and Medical Services
- MUAC - Mid Upper Arm Circumference
- NDMO - National Disaster Management Office
- NGO - Non Government Organisations
- NHCS - National Center for Health Statistics
- NOAA - National Oceanic and Atmospheric Administration
- PACCSAP - Pacific Australia Climate Science Adaptation and Planning
- PCCAPHH - Piloting Climate Change Adaptation to Protect Human Health
- PCCSP - Pacific Climate Change Science Program
- RCT - Randomised Controlled Test
- SAM - Severe Acute Malnutrition
- SNAP - Smoking, Nutrition, Alcohol and Physical inactivity
- SPCZ- South Pacific Convergence Zone
- SPREP - South Pacific Regional Environment Program
- UNFCCC - The United Nations Framework Convention on Climate Change

- UNICEF - United Nations Children Education Fund
- UNOCHA - United Nations Office for Coordination of Humanitarian Affairs
- VAT - Value Added Tax
- WAF - Water Authority of Fiji
- WHO - World Health Organisation
- WMP - Western Pacific Monsoon





# Chapter 1

## Introduction

### 1 Background

The Fifth Assessment Report of the intergovernmental panel on climate change (“IPCC report”) has stated that climate change is unequivocal since the 1950’s and the world continues to warm through the decades [Pachauri et al., 2014]. The IPCC report predicted that the warming temperatures would melt snow, increase sea levels, increase in the intensity of extreme events such as droughts, flooding, wildfires and cyclones. Marine and land animal species change their geographical zones as the global temperatures would increase [Pachauri et al., 2014]. The impact of climate change on human health is adding further burden to the global diseases. There has been new, and re-emergence of infections due to climate change. In the Pacific, these diseases are referred to as climate-sensitive diseases (CSD) and include dengue, diarrheal illness, leptospirosis and typhoid. Other climate-sensitive health risks are NCD-related illnesses, psychological impacts, malnutrition and limited accessibility to health services [World Health Organization, 2015]. Climate change effects have been increasing in frequency and intensity in Fiji over the years, and the predictions show that the trend continues. Fiji has been experiencing frequent extreme weather events from the last decade. The International Disaster Database website ([www. emdat.be/ emdat db/](http://www.emdat.be/emdatdb/)) reported that from 2006 to 2016, Fiji experienced thirteen episodes of natural disasters including floods, droughts and cyclones. The extreme weather events contributed to outbreaks of climate-sensitive diseases within the country.

Climate change measurements are done by measuring the atmospheric temperatures through an electronic maximum, minimum temperature sensors (EMMS), radiosonde (a balloon measuring device, fitted with transmitters) and using measuring instruments from aircraft. The sea surface temperatures are measured using free-floating measuring instruments which transmit readings to satellites and also by ships. The precipitation and humidity levels are measured using standard and automatic rain gauges, and the use of weather radar and satellites. Sea level measurements are measured using tide gauges and apart from sea level, temperature, salinity measurements are regulated through the satellite monitoring of drifting buoys [Global greenhouse warming, 2017, Hardy, 2003]. The primary purpose of this study is investigating the relationship between climate change variables (temperature, rainfall and humidity) and the prevalence of malnutrition in Fiji. The temperature was chosen as it is an indicator of global warming which is causing climate change. Relative humidity is a measure of water vapour in the atmosphere in relation to the

amount of water vapour the air can hold before rainfall [Barreca, 2012]. The total rainfall and relative humidity were also chosen as they are linked to temperature, as temperature increases there is a higher chance of evaporation and extreme precipitation. These climate parameters are measures on a daily basis in the nine strategically located weather stations in Fiji and available when requested. McIver et.al. (2012) used these climate parameters when using a time series Poisson regression model on monthly cases of diarrhoea and monthly rainfall in Suva, Fiji [McIver et al., 2012]. Grace, et.al (2012) used the temperature and rainfall parameters when looking at child malnutrition and climate in Sub Saharan Africa [Grace et al., 2012].

The increase in global temperature is a cause of climate change and causes variability in rainfall and humidity patterns which increases the risk of crop failures and the decrease in crop productions. It can lead to the low availability of food and thus increasing food costs which increases the risk of malnutrition to vulnerable people, mothers, children and those in poverty. This study is looking at the prevalence of children under the age of five in Fiji. Climate change is evident in Fiji through the manifestation of extreme weather events such as flooding and cyclones. After the aftermath of such events, the Ministry of Health always records outbreaks of climate-sensitive diseases. There are also outbreaks of other health issues such as malnutrition but not much attention given to it since it is not considered as severe as the other diseases. Malnutrition is also a complex and multidimensional issue, and there is a lot of causal factors and is the number one child killer in Fiji according to the Ministry of Health [Ministry of Health Fiji, 2015]. There were reports by statutory bodies and the media that there were also outbreaks of malnutrition reported in the country. Malnutrition was documented in Fiji in the 1950's by Bahr (1951) where three fatal cases of malignant malnutrition were studied [Manson-Bahr, 1951]. Findings from 2004 National Nutrition Survey showed Fiji Indian babies were more malnourished from birth to six months than I Taukei and other races and from six months onwards there were more I Taukei malnourished than the other two races [Schultz T. J et al., 2007].

Atalifo et.al (2016) found there were social factors such as poor quality and late introduction of supplementary foods, slow weaning process, poverty and poor sanitation background associated with the prevalence of malnutrition in his study [Atalifo et al., 2016]. However, there is limited research done to determine whether climate change is a risk to the increasing prevalence of malnutrition in Fiji. Hagos, et.al (2014) in their study found that there was an insignificant relationship between malnutrition and temperature in Ethiopia [Hagos et al., 2014]. Temperature might not have a direct impact on the malnutrition, but its effect on the environment contributes to malnutrition. Increasing temperatures dry the environment and increase the risk of drought, years of drought in Greater Horn of Africa is associated with child malnutrition. The dry season recorded the highest prevalence of wasting, as low rainfall affects crop production and availability [Chotard et al., 2010]. Increase in temperature causes variability in the rainfall patterns and Meshram et.al (2014) found in their research that prevalence of malnutrition in preschool children (stunting, wasting and underweight) in Odisha State, India. Malnutrition was significantly higher during the rainy season as compared with the incidence during the summer and the winter months [Meshram et al., 2014]. Grace K et al (2012) in their Kenyan study found that there was a definite relationship between the levels of precipitation and child stunting [Grace et al., 2012]. Studies by Keatinge, et.al (2010) and Gaire, et.al (2016) found that droughts and floods compound food shortages and exert pressure on the nutrition status of the country and there were significant relationships between disasters and stunting in children [Keatinge et al., 2010, Gaire et al., 2016]. Rodrigues -Llanes, et.al (2016) found that children exposed to frequent flooding in India had a higher chance of wasting to those exposed to one flood or no floods [Rodriguez-Llanes et al., 2016].

This study assessed if climate change through the changes in minimum and maximum temperatures, total rainfall and relative humidity can affect the prevalence of malnutrition amongst children between birth and five years in Fiji. The climate variables of temperature, precipitation and humidity were chosen as indicators of climate change as these were the most common and ideal way of measuring climate change and the data was available locally through the Fiji Meteorological Service who conducted daily measurements in nine weather station located around Fiji. The period 2006 to 2016 was chosen as it had years with extreme weather events and those without it. In that period Fiji experienced thirteen episodes of natural disasters, from tropical storms, drought and flooding. In 2006 Fiji had a cyclone and floods, and in 2012, there were two floods and a cyclone, a drought in 2015 and a category five storm in 2016. There were years in between where there were no natural disasters such as 2011, 2013 and 2014. Therefore it was an appropriate way to determine if the extreme weather events caused by climate change increases the risk of malnutrition than in years where there were no events. Therefore it was essential to determine if the manifestation of climate change through these storms have any association with the prevalence of malnutrition during these periods.

## 2 Thesis Aims and Objectives

The goal of this study is to assess the relationship between climate variability and the prevalence of malnutrition in Fiji. The objectives of the study are as follows:

1. Describe monthly variation in the temperature, humidity and rainfall in Fiji between January 2006 and December 2016.
2. Estimate the monthly average of malnutrition prevalence in Fiji between January 2006 to December 2016 for children from birth to sixty months.
3. Assess the association between variation of temperature, rainfall, and humidity with malnutrition prevalence from January 2006 to December 2016.

## 3 The Effects of Climate Change

Increase in global temperature has affected the global climatic system and subsequently impacted the natural environment and its inhabitants. The IPCC defines the climate system as an interdependent system having five components which are the atmosphere, the hydrosphere, the biosphere and the land surface which is altered by external forcing from the sun and the through unequivocal human activities. The IPCC 5th Assessment Report states that the rapid growth of industrialisation and urbanisation has contributed to the increase in greenhouse gas emission with significant increases in global temperatures recorded in the last 130 years (1888 - 2018). The thirty year period between 1983 to 2012 was the warmest in the previous 1400 years for temperatures recorded in the northern hemisphere [Alexander and Simon Bindoff, 2013]. The warming effect creates a change in the climatic patterns as it increases the melting of polar ice caps creating an increased volume of water in the oceans leading to change in the ocean currents and the thermocline [Pachauri et al., 2014]. The changes include fewer cold days and evenings but an increase in the number of warm days and evenings. The continents of Europe, Asia, and Australia experience an increase in the frequency of heat waves. North America and Europe be

the worst affected by the heat stress and cause many fatalities as people in temperate countries try and adapt to the rising temperatures [Pachauri et al., 2014].

Tropical cyclones have increased since the 1970's, in the 2004 season there were fourteen cyclones recorded in the North Atlantic and nine reached hurricane levels. The Eastern Pacific, West Pacific, North Atlantic, South Western Pacific, North Indian and South Indian basin all recorded an increase in cyclone activities when comparing 1975 - 1989 and 1990 - 2004 period [Webster et al., 2005].

Basin	Period			
	1975-1989		1990-2004	
	Number	Percentage	Number	Percentage
East Pacific Ocean	36	25	49	35
West Pacific Ocean	85	25	116	41
North Atlantic	16	20	25	25
Southwestern Pacific	10	12	22	28
North Indian	1	8	7	25
South Indian	23	18	50	34

Table 1.1: *The number and percentages of cyclones in the fifteen year periods 1975-1989 and 1990-2005 for the ocean basins of the world.* [Webster et al., 2005]

Climate-related events including droughts, heat waves, floods, tropical storm and wildfires have caused alteration to the ecosystem, disruption of food and water supply, infrastructure damage and increased human mortality and morbidity [Alexander and Simon Bindoff, 2013, Pachauri et al., 2014].

The increasing anthropogenic greenhouse gas emissions have warmed the ocean and increased evaporation causing the rising salinity levels. However, this is counterbalanced by fresh water from melting ice. Greenhouse gas emissions are gases that are produced by humans as a result of economic development, and countries with large development plans such as India and China are big emitters [Latif et al., 2009]. They are referred to as greenhouse gases as they add to the existing natural greenhouse gases in the atmosphere. The thermal expansion due to the warming of the ocean has caused sea level rise in some parts of the world such as the North Atlantic. The sea has become a significant sink for atmospheric carbon dioxide, where the ocean absorbs most of the carbon dioxide in the atmosphere, and this has altered the pH levels of the sea. The carbon dioxide decreases the pH levels and turning the ocean more acidic. A process is known as ocean acidification [Pachauri et al., 2014].

The IPCC AR 5 reported that Greenland and Arctic ice sheets have been melting rapidly since 1992. The melting rate of ice sheets from Greenland has significantly increased from 1992 to 2011 an increase from 34 (-6 to 74) Gigatonnes per year to 215 (157 to 274) Gigatonnes per year from 2002 to 2011. Melting glaciers and receding spring snow cover raised the sea level in the 20th century. Between 1901 to 2010 the sea level rose by 0.19 meters. Glacial ice loss and thermal expansion of oceans from global warming caused 75% of the mean sea level rise. The worldwide distribution of sea level rise is unequal due to the oscillation of the earth and movement of sea currents. It is the reason the Western Pacific sea level rise is three times more than the global mean [McMichael, 2003, Pachauri et al., 2014].

Rising temperatures resulted in altered forces driving to increase frequencies of precipitation, storms and adverse weather events across the world [McMichael, 2003]. The indication of ob-

served climate change effects is most vigorous and most extensive on the environment. In several localities, changing rainfall or defrosting snow and ice are changing the environment system, influencing water quantity and quality. Since the 1850's the world has been getting warmer, and the northern hemisphere was recorded to have the highest warming in the last three decades.

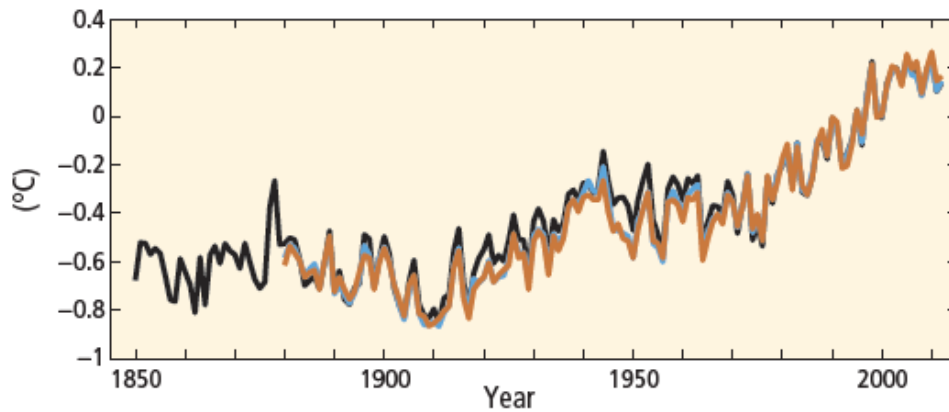


Figure 1.1: *The figure shows the combined average land and ocean surface temperature anomaly 1850-2012 . The combined land and ocean temperatures show an increase from the 1900's onwards.*

[Pachauri et al., 2014]

The graph in Figure figure 1.1 from the IPCC report provides evidence of the warming climate, the combined land and ocean temperature increased steeply since the 1980's. The increasing global land and ocean temperature are disrupting the climatic system. All living things on earth have adapted to the climate and environment in which they live, and any changes to the climate system threaten their resilience and ability to adapt. An understanding of how climate change happened or works is needed to address the issues associated with it.

The United Nations Framework Convention on Climate Change (UNFCCC) has defined climate change as

the direct and indirect impacts of human activities altering the global composition of the atmosphere in addition to the natural climate variability over specified time

[Pachauri et al., 2014]

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as using statistical analysis to determine changes in climate variables over time, usually in decades or more [Pachauri et al., 2014]. Global warming refers to the increase in temperature and climate change relates to the "changes" in the climate as a result of the increased temperature of the atmosphere. Global warming is the cause of climate change which also causes variation in the rainfall patterns and humidity.

Scientists can trace back past climates using the natural resources in the environment. Palaeoclimatology is the study of climate before the use of monitoring equipment. Tree rings are precise measurements as it contains dated information about the past climate [Salinger, 2005]. In determining the effects of the climate of Qinghai-Tibetan Plateau, China, scientists looked back at the past climate through tree rings and ice cores and found that variations in temperature and rainfall were significant in the past millennium [Huang and Zhang, 2007]. Corals also pro-

vide information on the past climate variability of the tropical and subtropical oceans. As coral are sensitive to changes in ocean temperatures and salinity, studying modern, and fossil corals identify variation in the sea surface temperature and the sea surface salinity during the past millennium [McGregor, 2011]. Ice cores from the Polar Regions provide the climate information of Greenland and Antarctica. Other sources are boreholes providing temperatures in Europe and China, and the glacial moraines show evidence of past cold avalanches [Salinger, 2005].

The global average temperature has increased by 0.6 degrees Celsius since 1860. There are anomalies in the surface air temperatures between the northern and the southern hemispheres. Two significant temperature increases of 0.14 °C in 1910 - 1945 and 0.17 °C in 1976 - 1999. The global precipitation levels also rose by 2%, but the distribution levels were different for the north and the southern hemispheres. The equatorial and some subtropical regions recorded decreases in precipitation levels [Salinger, 2005]. The figure 1.2 from IPCC AR 5 indicates that the global temperature and precipitation levels have increased from the previous century. However, temperature and rainfall levels are unequally distributed worldwide as some areas can receive extreme levels while others receive lower than normal readings. The changes in atmospheric and ocean temperatures in the past have confirmed that climate change has been happening in the pre-industrial age.

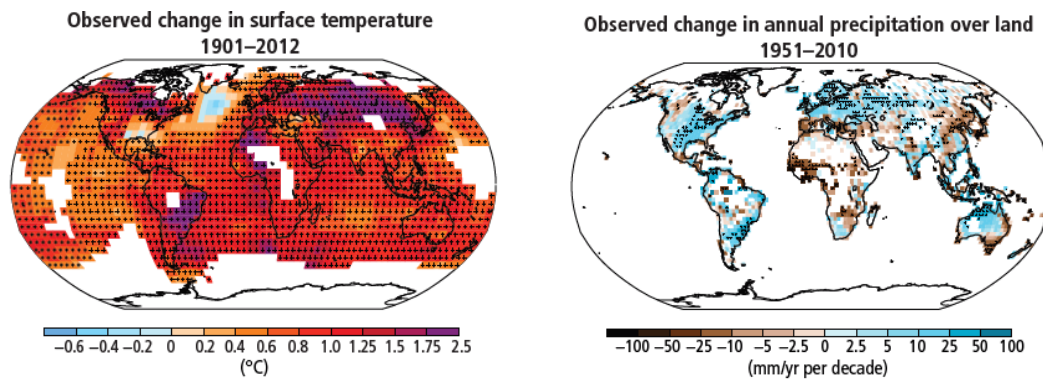


Figure 1.2: The figures show the observed changes in surface temperature and precipitation. The first figure shows that the global surface temperature from 1901 - 2012 is increasing in the different location around the world. The dark red spots indicate the significant increases in temperature in that location. The next figure shows the annual precipitation from 1951 to 2010, which shows the variation in rainfall patterns with brown showing the least and dark blue the most.

[Salinger, 2005]

### 3.1 Causes of Climate Change

#### Sunspots

Climate change is said to be caused by internal and external factors. External factors cause the variations in solar energy reaching the earth caused by sunspots on the Sun. Sunspots are dark regions on the surface of the sun's photosphere. They are dark because they are cooler and emit less energy than other parts of the sun. The sunspots temperature is about 1227°C less than other parts of the sun, and during the period when the sun has sunspots, its radiation towards the earth is reduced, and this varies from decades or longer. The sunspots are enormous areas and

are sometimes ten times more the diameter of the earth. The little ice age of the 17th century, when the world was unusually cold correlated with a few sunspots [Hoyt and Schatten, 1997].

### Rotation of the earth

Another factor that causes external variation in solar energy on earth is due to the rotation of the planet and tilting on its axis, and its orbit around the sun which determines the yearly and half-yearly cycles. Discovered in the early 20th century Milankovich cycle is the varying of the earth and the sun geometry over time, and it has three effects. The eccentricity which occurs every 100,000 years cause's solar irradiance to vary between seasons, a tilt which happens every 41,000 years and precession influences heat distribution between latitudes and play essential roles in the triggering of the ice ages when radiation is reaching the higher latitudes. The tilting of the poles towards and away from the sun varies and has a direct effect on the temperature and the seasons on the planet [Bennett, 1990, Latif et al., 2009, Wallington et al., 2009]. The external factors cause the unequal distribution of solar energy or warming on earth.

### Natural variation

The other factor that is driving climate change is through the internal factors. It is the natural cycle of the variations in the solar energy reaching the land, the energy gained and energy lost back into the atmosphere. Radiative forcing causes interactions between the air and the ocean in which affects the currents oscillations and causes changes in weather patterns around the world and examples of this include the El Nino Southern Oscillation (ENSO) in the Pacific and the Gulf Stream [Ganopolski, 2008]. A geological process such as volcanic eruptions also causes variations in climate. The dispersal of sulphuric aerosols from volcano causes variations in solar energy towards the earth, aerosols absorb and release long-wave radiation and also absorb and reflect infra-red solar radiation. The smaller particles from the eruption rise to the stratosphere and vast coverage area of the earth and solar variation depend on the strength of the eruption and geographical location of the volcano [Bertrand et al., 1999, Latif et al., 2009]. The sulphur particles reflect the radiation from the sun causing a drop in temperatures and global cooling. The *Krakato* and *Pinatubo* volcanic eruptions in 1883 and 1991 caused drop in global temperatures to between 0.1 to 0.2°C [ColeDai, 2010]. The supervolcano erupted in 1815 at *Tambora* in Indonesia had a catastrophic effect in Europe and America as 1816 was known as the year without a summer, causing astronomical agricultural failures and fatalities [Brönnimann and Krämer, 2016].

### Albedo effect

Another internal factor is the albedo effect. Albedo or reflectivity is when the solar power from the sun is reflected back into space. The indication of albedo is a number between 0-1, where 0 is the dark surface, and 1 is the lighter surface. The average world albedo is 0.3 which means that 30% of the incoming solar radiation is reflected back into space. Reflectivity is more on the lighter surface of the earth like ice sheets, snow covers, deserts and clouds than in the darker surfaces of the earth such as vegetations and ocean surfaces. The reflectivity affects the earth's climate when energy and heat are reflected back into space. It was one of the reasons for the variations in the global temperatures between the ice ages and during the industrialisation period [Cronin, 2010, Stephens et al., 2015].

### Greenhouse effect

The rate of change of gases in the atmosphere is a natural phenomenon known as the natural greenhouse effect. The sun radiates energy down towards earth through visible light or short-wave radiation. The greenhouse gases in the atmosphere, nitrogen, oxygen and carbon dioxide are transparent to short-wave radiation. Most of the shortwave radiation gets reflected back to space by clouds, deserts and light coloured reflective surfaces like ice caps and ice sheets. The other shortwave radiation that gets through warms the earth surface and radiates energy back to space as long-wave radiation or infra-red radiation. The atmosphere is however not transparent to outgoing infra-red radiation. The carbon dioxide molecules absorb the energy and re-emit it back to earth as heat. The remaining gases are either absorbed by other greenhouse gases or escape into space. If all the incoming solar energy is reflected back into space, the average surface air temperature would be  $-16^{\circ}\text{C}$ , making the world a cold planet. However, due to the greenhouse gases absorbing the solar radiation, the average surface air temperature is about  $14^{\circ}\text{C}$ . The figure 1.3 illustrates the energy cycle from the sun to the earth. This occurring natural exchange of energy has warmed the earth and allowed for life to thrive. The concern is the more carbon dioxide molecules in the atmosphere has increased the interception of the long-wave radiation and retaining the heat back on earth [Cronin, 2010, Latif et al., 2009, Trenberth, 2009].

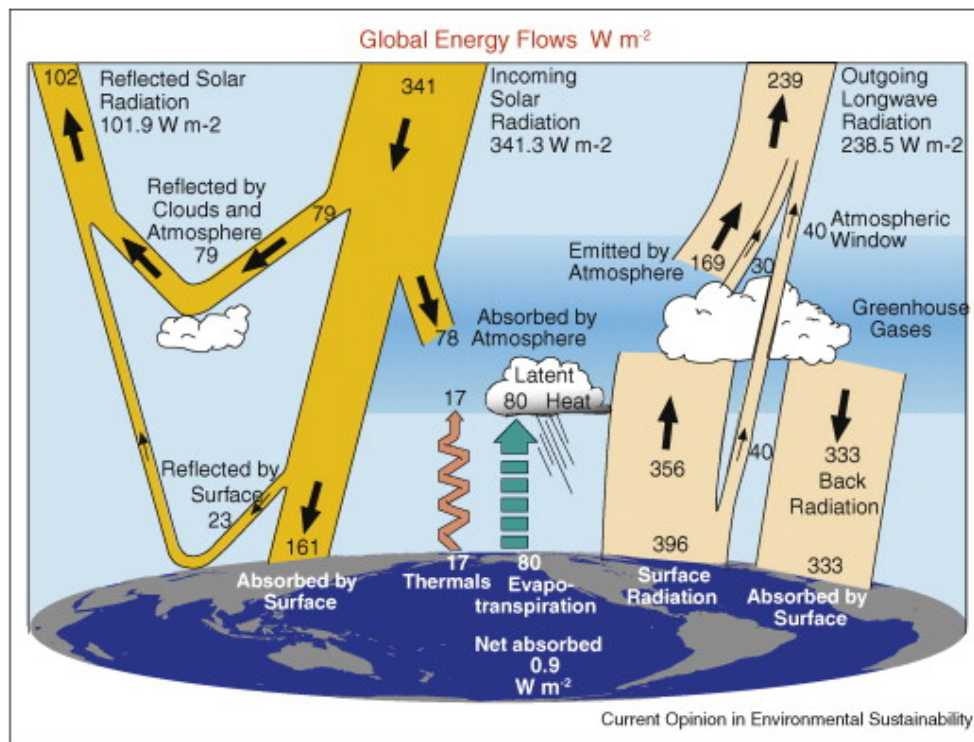


Figure 1.3: The figure shows the Earth's Energy Flow. The figure has arrows that demonstrate the amount of incoming solar radiation from the sun and the amount of outgoing longwave radiation. It shows the amount reflected by the clouds and the atmosphere and other surfaces. It also shows the absorbed by the earth surface and the atmosphere.

[Trenberth, 2009]



### Coriolis effect

The variability in the solar radiation also affects the Coriolis forces which are factors that drive air currents. The equator receives most of the incoming solar radiation about three times more than the poles, and it causes a significant thermal gradient between the equator and the poles [Cronin, 2010]. Coriolis effect is an inertial force defined in 1835 by French engineer-mathematician Gustave-Gaspard Coriolis [Graney, 2017]. Coriolis effect is the movement of the wind and ocean due to the rotation of the earth, and it changes the atmospheric and the ocean's systems as they move towards the poles. The rotation of the earth is faster at the equator than the poles, affecting wind patterns in different localities. In the northern hemisphere hurricanes move in an anti-clockwise and the southern hemisphere it moves in a clockwise manner. It causes the movement of the wind and the oceans to curl to the right in a clockwise direction in the Northern hemisphere and curls to the left in the Southern hemisphere in an anticlockwise direction [Cronin, 2010, Hardy, 2003]. Climate change is a natural phenomenon that has been happening for thousands of years from internal and external factors mentioned above. However, there is an increase in greenhouse gas emissions into the atmosphere since the last century that has caused global warming.

### Human Activities

Human activities have contributed to the increase in greenhouse gases and contributed to global warming and climate change. In 1896, a Swedish chemist Svante Arrhenius predicted that climate change would occur due to human activities. He referred to the increasing global industrialisation where a majority of fossil fuel would be used thus increasing the amount of carbon dioxide in the atmosphere. Svante Arrhenius predicted that carbon dioxide would significantly increase and cause global warming [National Aeronautics and Space Administration, 1998, Hardy, 2003, Wallington et al., 2009].

The National Oceanic and Atmospheric Administration (“NOAA”) of the United States is an agency that carries out systematic studies on the ocean, atmosphere and ecosystems through observations and modelling [Dlugokencky and Trans, 2017]. Worldwide Observing Division of NOAA/Earth Framework Exploration Research facility has measured carbon dioxide and other greenhouse gases for decades using equally distributed sampling sites worldwide [Conway et al., 1994]. The graph on figure 1.4 shows the data collected for the last four years. The red line symbolises the monthly mean values, and the black line represents the same after accounting for the average seasonal cycle. The graph shows the global average concentrations of carbon dioxide in the atmosphere is on a steady upward trend [Dlugokencky and Trans, 2017].

The IPCC glossary defines anthropogenic climate change as when humans interfere with the natural gases in the atmosphere which in turn influences the change in average weather and climatic conditions [Pachauri et al., 2014]. According to the IPCC 5 AR, anthropogenic greenhouse gas emissions have increased after the industrial era, and the trend is rising due to economic and industrial growth. The concentration of carbon dioxide, methane and nitrous oxide have reached an all-time high in the last 800,000 years. Anthropogenic emissions and natural climate variability are causing changes in the climate systems. Carbon dioxide increased contribution to radiative forcing from 1750 to 2011, with the upward trend from 1970 onwards. Data collected between the 1750's and 2011 revealed that carbon dioxide concentration in the atmosphere stood at  $240 \pm 310\text{Gt}$ . The oceans absorbed approximately 60% of the anthropogenic greenhouse gas emissions and store them in the land and plants with the remaining 40% retained in the at-

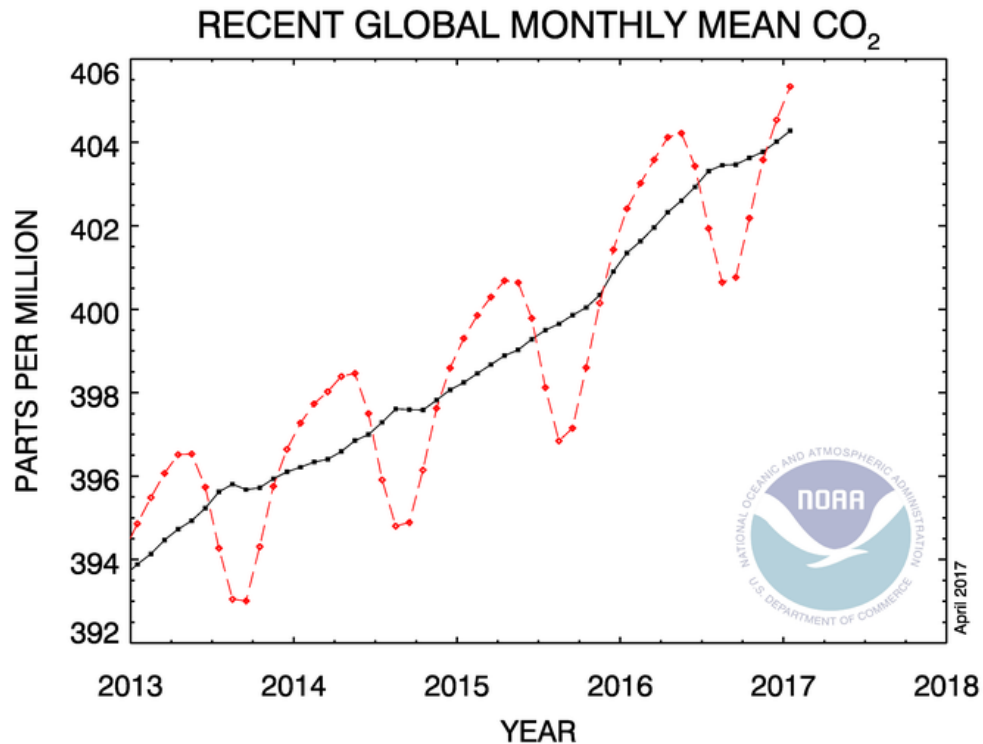


Figure 1.4: *The figure shows the Global Monthly Mean of carbon dioxide levels . The overall trend of the global mean carbon dioxide concentrations shows a steep increase in the past four years. The global monthly mean carbon dioxide seasonal cycle is also showing an upward trend.*  
[Dlugokencky and Trans, 2017]

mosphere [Pachauri et al., 2014]. The earth's surface has been progressively hotter than any of the last ten years since 1850. The warmest 30 year period was between 1983 to 2012, and it was the warmest recorded in 1400 years in the Northern Hemisphere. The readings of the combined average land and ocean surface temperature between 1880 to 2012 showed a linear trend of warming of 0.85 [0.65 to 1.06] $^{\circ}$ C over the period 1880 to 2012 [Pachauri et al., 2014]. Human activities have exerted pressure on the global climate system and create new challenges to ensure human well-being [McMichael, 2003]. Anthropogenic climate change is a result of rapid growth of development for economic success has exerted pressure on the environment. The former United States President, Barack Obama claimed that

“ climate change is the most important threat to humanity in this century.”

during the Climate Summit in New York in 2014 [Franchini and Mannucci, 2015]. Climate change was a naturally occurring phenomenon that was occurring over millennia, and human activities have accelerated the rate of climate change through the excessive emissions of greenhouse gases into the atmosphere. Climate change is altering the ecological cycle and affecting wildlife and most importantly threatening human existence.

### 3.2 How Climate Change has an impact on Health

Climate change threatens human health. Climate change challenges the basic health and human rights necessities which is proper shelter, clean air and water and adequate supply of nutritious food [World Health Organisation, 2009]. Climate change pathways affecting human health are complex through direct, indirect, and diffuse means also referred to as primary, secondary and tertiary effects [Butler and Harley, 2010, McMichael, 2013]. Primary effects are direct effects of climate change on human health which includes injuries caused by extreme weather events which are predicted to intensify due to climate change. Examples of primary or direct impacts include heat strokes from heat waves, injuries and deaths from severe weather events and respiratory illnesses from increased urban air pollution [Butler and Harley, 2010, McMichael, 2013]. High temperatures are more frequent during the summer at high latitudes and increase the risks of heatstroke, and the South Asian heat waves caused a high mortality rate amongst day workers and the elderly [Ahasan, 2010, O'Dwyer et al., 2016]. Europe recorded the hottest summer in 2003 with temperatures rising to 3.5 °C above average. In August 2003, approximately 22,000 to 45,000 heat-related deaths reports came from across Europe [Patz et al., 2005].

The secondary effects are risks caused by changes in the biosphere and environmental surroundings especially in water supply, crop yields and disease vectors [McMichael, 2013]. The secondary effect has a more lengthy impact than the primary effect, and it is a cause and effect especially for infectious diseases [Butler and Harley, 2010]. Infectious diseases interaction between humans and its host is affected by changing climate conditions. Vector-borne diseases such as dengue and malaria are sensitive to sensitive to rainfall and increase in temperature. An increase in temperature reduces the incubation period of mosquitoes, while droughts contribute to the increase in dengue when humans store water in drums which are ideal breeding places for dengue vectors [Butler and Harley, 2010, McMichael, 2003]. Research carried out in the Asia Pacific, South America and South Asia have reported that El Nino Southern Oscillation cycle (ENSO), which is a short-term variation in weather, was positively correlated to malaria and dengue fever epidemics [Ahasan, 2010, Bouma and Kaay, 1996]. Dengue is also projected to increase due to variability in temperature, precipitation and humidity [Franchini and Mannucci, 2015]. Other vector-borne diseases such as leptospirosis and tularemia are also expected to thrive from the variation in climate. An outbreak of leptospirosis in Brazil and Nicaragua after frequent flooding in 1995. A cross-sectional study found that people who had contact with flood waters were fifteen times more at risk from contracting leptospirosis [McMichael, 2003].

Tertiary effects occur due to the interaction between the environment, climate change and politics [Butler and Harley, 2010]. Examples of these include mental health-related illnesses due to displacement and conflict caused by depleting resources such as food, water and shelter, in turn, caused due to climate changes [Ahasan, 2010, McMichael, 2003]. The increase in sea level cause displacement of millions of people from low lying areas [Butler and Harley, 2010]. Albrecht, et.al (2007) and Berry et.al (2009) found that Australians were having high levels of psychological stress when they were exposed to environmental degradation and interruption to their agricultural activities through extreme weather events such as prolonged droughts. There has been an association between severe droughts with detrimental mental health disorders such as severe anxiety, depression, chronic psychological stress and increasing suicide rates [Albrecht et al., 2007, Berry, 2009]. Mental health issues were mainly affecting older farmers who are overwhelmed by a sense of loss due to the prolonged droughts, and the lack of access to mental health services and support further compounds the issue [Polain et al., 2011].

Climate change impacts through degradation or destruction of the environment may aggravate

the loss of cultural and traditional heritage of indigenous people. It contributes to increased levels of stress leading to substance abuse and suicide [Albrecht et al., 2007]. The indigenous people of Canada, the *Inuit* showed signs of stress and distress as the receding ice has disrupted their travelling, hunting and fishing. They showed a strong emotional connection with their land, their identity and their culture, and the loss of these has increased the risk of drugs and alcohol usage and the idea of suicide [Cunsolo Willox et al., 2013, Cunsolo Willox et al., 2013]. Climate change affects humans in many complex ways as described above, and the figures stated are what is being experienced. The further increase in temperatures as predicted by the IPCC increase the risk of health issues discussed above.

The vulnerability of populations varies with geographical location, which means that some parts of the world will be more vulnerable than others [World Health Organisation, 2009, O'Dwyer et al., 2016]. The density of the population, economic status, existing environmental conditions, and accessibility to quality health services determine the level of vulnerability [McMichael, 2003]. Those who are vulnerable or at risk of extreme weather events include those residing in isolated communities with limited resources to adapt or have poor mitigation measure [McMichael, 2003]. It contains small island states like Fiji where its tropical location makes it vulnerable to frequent cyclones and other extreme weather events. An example of this was the cyclone Winston in 2016 where high mortality was recorded from remote communities in the rural and maritime areas. These communities are close to the sea and rivers, and most are far from the primary health services which makes them vulnerable to the effects of climate change. Those living on the border of dengue and malaria with poor health services be vulnerable as the disease expand its geographical range due to the warming climate [McMichael, 2003]. Most of the developing countries exposed to frequent extreme weather have vast portions of their GDP utilised in the recovery and rehabilitation after such events [Ravindranath and Sathaye, 2002]. Cyclone Winston which affected Fiji in 2016 caused damages and loss to lives and infrastructure worth F\$1.42 billion which was equivalent to 31% of the GDP [World Bank, 2016].

Climate change is causing many changes in the environment, and this has affected all inhabitants of the world from animals to human beings. Several terrestrial, freshwater and marine species have shifted their geographic ranges, migration, and breeding patterns in light of progressing environmental change [Patz and Kovats, 2002]. The most vulnerable to the effects of climate change are humans, especially those in developing countries with limited resources to adapt and mitigate the effects and those in small island developing states like the Pacific and the Caribbean. Climate change threatens human health in various ways and forms. Climate change increases the risk of injuries and deaths during severe weather, increases the geographical range of vector-borne diseases and cause overcrowding when rising sea levels displace people.

Increased temperature leads to the manifestation of climate change such as variation in rainfall patterns, and this affects agricultural productions and availability of food. Climate change increases the likelihood of crop failures leading to food shortages. In turn, this is likely to increase the risk of malnutrition in countries that are dependent on agriculture to supply food to their citizens. Climate change affects food availability through direct effects, the variation in rainfall causes either floods or droughts, the difference in temperature modifies the length of the crop growing seasons [Gregory et al., 2005]. In semi-desert areas or semi-arid regions, droughts significantly reduce crop yields, livestock numbers and total production. These are countries in the Sub Saharan Africa and South East Asia which are developing countries with already soaring levels of child malnutrition be exposed to a higher instability of crop production [Bruinsma, 2017]. Reduction in crop yield and livestock production due to climate change increases the risk of food availability and accessibility. Vulnerable populations and families that spend two-thirds of their

income on food start to ration food. They usually purchase more rich calorie foods with poor nutritional status and cause an increase in micronutrient malnutrition, especially amongst children [Bloem et al., 2010]. Children near or surrounding deserts are exposed to the intense heat and harsh environment conditions reducing their food sources and food intake [Singh et al., 2006].

Adams, et.al (1998) in their study on the effects of global climate change on agriculture discussed that increase in temperature reduces the livestock appetite and thus cause weight loss and also affects the quality and quantity of milk produced. Rising temperatures also increase respiration rates in plants, produces small and low-quality grains subsequently lowering the crop yields [Adams et al., 1998]. These are factors caused by global warming that affect the agricultural sector and the livelihoods of people who depend on it.

The agricultural systems depending on irrigation are vulnerable to reduced rainfall levels and high evaporation loss. Increase in temperatures would influence the life cycle of plant pests and insects, which also hinders crop production [McMichael, 2001]. Crop models are statistical estimations of weather, soil conditions and crop management to predict crop yields, maturity and effectiveness of fertilisers, it uses computer simulation programs to copy the growth and the development of crops [Arora-Jonsson, 2011]. Crop models have predicted that climate change affects crop productions, as crops try to respond to the changes in temperatures, precipitation levels and increasing levels of carbon dioxide.

Crop and livestock yields would be most affected by the changes in climate variables [Adams et al., 1998, Parry et al., 2004]. High-intensity rainfalls damage younger plants and quicken the ripening of grains in standing crops, and it also increases the risk of soil erosion [Rosenzweig et al., 2001]. A study in India found that prevalence of malnutrition was high in preschool children during the rainy season compared to other seasons. The rainy seasons were known as the lean period where there was limited grain available at home [Grace et al., 2012]. There is a high incidence of underweight in the highlands during low or high rainfall [Hagos et al., 2014]. Climate change causes an increase in demand for food supplies. The variation in rainfalls and temperature and the increase in the frequency of extreme climate events are affecting crop productions and causing this short supply [Bloem et al., 2010]. The short supply of food increases the food prices and children in poor households are vulnerable to underweight as families try and manage the food shortage [Tirado et al., 2013]. Climate change is causing much havoc within the agricultural sector and consequently affects food and nutrition security to countries in the Sub Saharan Africa, South East Asia and also in the Pacific Islands.

### 3.3 The impacts of Climate Change on Health in the Pacific Islands

The variation in rainfall caused by climate change have an effect on crop productions in the Pacific. The rising temperatures, climate variabilities such as El Nino and La Nina conditions, sea level rise and more intense cyclones also affect the agriculture sector. Many of the rural dwellers in the Pacific still rely on locally grown food as their main staple diet. Most of these crops are dependent on rains in the summer (November to April), so the plants are dependent on rainfall. Climate projections for the region are variations in total rainfall which would be catastrophic to the crops [Food and Agriculture Organisation, 2008]. Subsistence farming is prevalent throughout the Pacific with a few venturing into commercial activities for domestic and international markets. Coastal regions experience contamination of groundwater and estuaries from the intrusion of salt water and frequent storm surges which can individually, or a combination affect food productions [Barnett, 2011]. The increase in rainfall is beneficial to some crops such as coconut, breadfruit and cassava while the decrease in rainfall is not suitable

for most crops especially the staple crops taro and yams. The tuna stock in the Central and the Western Pacific is expected to decline due to the increased salinity levels from increased absorption of carbon dioxide in the ocean and the increasing ocean temperatures from moderate El Ninos and ENSO [Timmermann et al., 1999]. The super El Nino of 97/98, Fiji lost F\$104 million worth of sugarcane and F\$15 million of other crops and livestock [McKenzie et al., 2005]. The tropical cyclone Ofa that hit Niue in 1990 turned the country from a food exporting country to an importing one for the next two years [Food and Agriculture Organisation, 2008]. It makes the population in Niue vulnerable to micronutrient malnutrition as fruits, vegetables and staple diets are being replaced by imported food. The increase in temperature enhances the growth of pathogens especially bacteria, maximising the risk of food-borne illnesses. Temperature and time are essential in food safety. Therefore, warmer temperatures have been known to increase the risk of pathological contamination in food. Food poisoning and typhoid fever is caused by a microorganism called *Salmonella*, and others such as *Shigella*, *Campylobacter* and a host of other viruses [Britton et al., 2010, D’Souza et al., 2004, El-Fadel et al., 2012]. Symptoms of Food poisoning and typhoid include diarrhoea and children who have episodes of diarrhoea are at risk of being malnourished [Allen and Gillespie, 2001]. Pacific Island countries are small in size and limited land areas for cultivation, and frequent extreme weather events, coastal inundation, have enormous consequences on their agricultural sector [Food and Agriculture Organisation, 2008]. It also makes them more depended on imported food which is usually high in sugar and fat. Subsistence and commercial crops were affected by Cyclone *Ami* that hit Fiji in 2003 were estimated to be F\$66 million. Niue, Tuvalu, and Vanuatu also had significant effects on their agricultural industry, but there was no available data to quantify the magnitude of this impacts [Sharma, 2007]. In the Pacific, food crisis is connected to natural disasters, as crops for commercial and personal consumptions is affected. The access to the primary centres from the rural areas is cut off from flooded roads. Thus the food supply is disrupted. During disasters, food supply is sometimes delayed and causes food crisis to last for weeks, depending on the severity of the catastrophe [Sharma, 2007]. The delay in the food supply to affected areas increases the risk of malnutrition, especially amongst children. Climate change increases the risk of malnutrition in the Pacific Islands through the increased temperatures and variation in rainfall disrupting crops and providing an ideal environment for pathogens that cause diseases in plants and humans. The lack of vegetables, increase the demand and raises the prices and leaving poor households vulnerable and at risk of malnutrition. However, there is no clear linkage between the effects of climate change on the prevalence of malnutrition in the Pacific.

Climate change also contributes to other health issues in the Pacific. The Pacific Islands are exposed to the impacts of climate change through the increase in the frequency of extreme weather events and are one of the direct pathways that climate change affects human health [World Health Organization, 2015]. Extreme weather events such as floods and tropical cyclones pose direct threats through severe injuries and even deaths. The indirect impacts increase illnesses from vulnerability to lack of water supply, food supply, and safety after disasters. Climate change is expected to increase the burden of health significantly from future climate-related disasters (floods, droughts and cyclones) in the Pacific [Field, 2012, Mahany and Keim, 2012]. Floods and droughts are extreme weather events caused by variations in precipitation levels exert pressure on the water security issues in the Pacific Islands [McMichael and Lindgren, 2011]. Urbanisation, housing, tourism, and agriculture have altered land use and exerts pressure on current water resources in small island environments [Pachauri et al., 2014]. The effect of heat stress in temperate countries is well documented, Pacific islands also feel the effects of the increase of atmospheric temperature. There is currently a study in Fiji on the relationship between temperature and mortality [World Health Organization, 2015]. Vulnerable populations are least

likely to adapt to the changing climate because they are poor and cannot fund adaptation measures such as purchasing quality food after food crisis, as food prices usually soar during these periods. Children are also vulnerable as they have weak immune systems which are susceptible to diseases such as diarrhoea and typhoid from consuming contaminated food and water in rural areas after a natural disaster. Some epidemiological studies conducted in Europe have found a positive association in the increase in temperature (heat waves) and mortality in older adults especially women [McMichael et al., 2006]. The vulnerable population include children, the elderly, the chronically ill, the disabled, and people with jobs that expose them to heat such as farmers and factory workers [Kjellstrom et al., 2009]. Climate change increases the risk of health effects of vulnerable countries such as the Pacific Islands who are at the forefront of climate change impacts. Vulnerable populations such as women, children, the mentally ill and elderly are most likely to be affected by the increase in temperature, variation in rainfall and increase in the intensity of extreme weather events. Fiji like its neighbours in the Pacific is facing similar health risks from climate change.

### 3.4 Climate Change and Health in Fiji

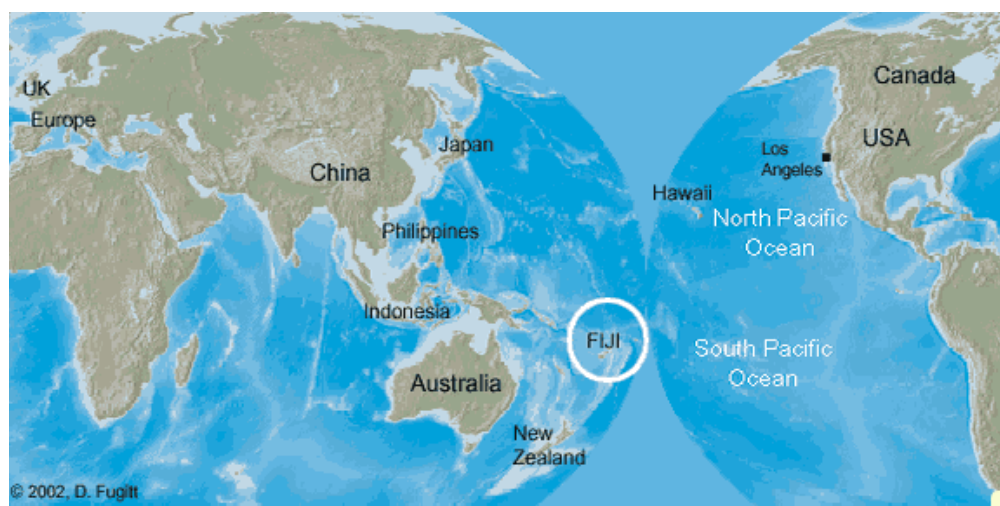


Figure 1.5: The figure shows the Map of Fiji and Fiji's location in the World. Fiji is located in the middle of the South Pacific and is near Australia and New Zealand

Fiji like other Pacific Islands is vulnerable to the effects of climate change that cause health burden to the country. The significant effects are on human health as the changing environment bring about new challenges in managing climate-sensitive diseases. There have been investigations carried out between the relationship of epidemics of climate-sensitive conditions and extreme weather events [World Health Organization, 2015]. These investigations include the relationship between floods and floods caused by tropical cyclones with dengue fever and diarrhoeal disease. The interpretation of the data for the Ba medical subdivision argued that there be a healthy association between the natural climate disasters and climate-sensitive diseases such as dengue and diarrhoea [McIver et al., 2012]. The results on table1.2 showed the odds ratio (OR) of climate-sensitive disease (CSD) outbreaks in Fiji after extreme weather events in Ba, Fiji. The table shows the strong relationship as the odds is high for dengue or diarrheal outbreak

to occur after a natural disaster event. It means that the chances of the outbreaks happening a month after the natural disaster is high. In the 1997/1998 El Nino period, there was an outbreak of dengue fever in Fiji, affecting 24,000 people and killing 13 [Ebi et al., 2006]. The rise in temperature during the El Nino caused an increase in the mosquito population the epidemic cost the country US\$ 3-6 million [Colbert, 2000].

Extreme weather event	Odds ratio (OR) of SCD outbreak in the month following the event
Drought	Dengue fever: OR = 5.17 Diarrhoeal disease: OR = 9.0
Floods caused by tropical depression	Dengue fever: OR = 5.57
All floods	Diarrhoeal disease: OR = 3.5

Table 1.2: *The tables presents the odds ratios of climate-sensitive diseases (CSD) epidemics after flooding and cyclones in Ba subdivision, Fiji* . The table is adapted from WHO, 2015. [World Health Organization, 2015]

The South Pacific Regional Environment Program (“SPREP”) warned Fiji that if it ignores the possible effects of climate change, which include increased vector-borne disease and increased malnutrition due to food shortages during extreme weather events, it loses US\$5 -19 million by 2050 [Ebi et al., 2006]. The 1997/1998 El Nino event that affected the Pacific including Fiji brought about severe drought conditions. The prevalence of micronutrient deficiencies was seen in pregnant women in areas severely affected by the drought. The prolonged drought caused by the El Nino phenomenon also caused diarrheal and malnutrition outbreaks [Ebi et al., 2006, McMichael, 2003]. Climate change is transforming the frequency and the distribution of climate-sensitive diseases in Fiji. It also costs the country millions of dollars in trying to control the illnesses.

The manifestation of climate change through extreme weather events in Fiji has contributed to the increase in the prevalence of climate-sensitive diseases. The events have also caused devastation in the agriculture sector with farms and crops destroyed by cyclones, floods and droughts. The reduction in crop production increases the risk of malnutrition of pregnant mothers and infants, and that is the area of interest in this study. Skolnik, (2016) states that malnutrition is a vital determinant of health status and has an essential bearing on the mother’s pregnancy outcome and health of the child. It determines the birth weight of a child, the development of their cognitive systems and the strength of their immune systems. The most critical concern is breastfeeding, and whether people have sufficient access to better nutrition [Joseph, 2017]. The following subtopic discusses malnutrition in detail.

## 4 Malnutrition

The United Nations Children Education Fund (“UNICEF”) defines malnutrition as

“ when the body does not get the proper amount of energy (calories), proteins, carbohydrates, fats, vitamins, minerals and other nutrients required to keep the organs and tissues healthy and functioning well” [UNICEF., 2010].



It occurs as a result of a composition of poor diet and infections which aggravate energy and nutrient loss through diarrhoea and vomiting. The nutrients, proteins, and energy in the body affect the body metabolism and determine the body shape, weight, and composition [Meier and Stratton, 2008]. Malnutrition also refers to those that do not get the right nutrition, and it can be more or less or the wrong kind. Those that have insufficient nutrients and energy are known as "undernourished", "stunted" and "wasted" [Skolnik, 2016]. The prevalence of malnutrition is determined by certain standards using the cut off value tool [Meier and Stratton, 2008]. The World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF) came up with the cut-off criteria to determine severe acute malnutrition (SAM) in children between 6-60 months. The WHO and UNICEF used the SAM and mid-upper arm circumference (MUAC) as indicators. As seen in table 1.3 children with the less than -3 standard deviations for weight and height were classified SAM and those with less than 115cm MUAC had severe wasting [World Health Organization and UNICEF, 2009].

*Adapted from World Health Organisation and UNICEF*

Classification	Index Used	Moderate	Severe
Underweight	Weight for age	<-2 Z -scores	<-3 Z-scores
Wasting	Weight for length/height	<-2 Z -scores	<-3 Z-scores
	Mid Upper Arm Circumference (6-59 months)	<126mm	<115 mm
Stunting	Length /Height for Age	<-2 Z -scores	<-3 Z-scores

Table 1.3: *Definitions for underweight, wasting & stunting based on anthropometric indices* [World Health Organization and UNICEF, 2009]

The World Health Organisation classifies malnutrition into three categories,

"undernutrition which includes wasting (low weight for height), stunting (low height for age), and underweight which is a low weight for age" [World Health Organisation, 2017].

Micronutrient malnutrition which is either lack of or excess of specific nutrients in the body and overnutrition which is excess nutrients in the body causing overweight and obesity are the other types of malnutrition [World Health Organisation, 2017]. Wasting and stunting were introduced in 1970's by John Waterflow in differentiating the difference between underweight and low weight with height (wasting) and children who are small for their age (stunting) [Waterlow, 1972]. Stunting and wasting occur when there is insufficient energy intake in the body, the body makes adjustments and draws fuel from the muscle and fat to ensure critical organs such as the heart, kidney, lungs, kidney are fully functioning. If this is sustained during the growing period (childhood), then there will be changes in the internal organs and it increases the risk of diseases relating to those organs during adulthood. Wasting and stunting change the makeup of the body since it decreases muscle and fat. Children are at a higher risk because they are growing and have a lower muscle mass compared to their body than in adults [Briend et al., 2015]. Children are one of the vulnerable groups in the population to malnutrition, and hence the study will look at the prevalence of malnutrition amongst children from birth to sixty months. It is the period where they are most susceptible to malnutrition as this is the growing period as mentioned in the Briend et al (2015).

Malnutrition does not only mean undernutrition, but it also means overnutrition or inappropriate protein calorie intake. A high weight for age indicates overweight. The unlimited amounts of

energy, carbohydrates and fat intake is a cause of overweight and obesity which is measured using the body mass index. This type of malnutrition is linked to increased risks of heart diseases, and diabetes and the trend are increasing in developing countries which has recorded a global increase of 12% in 2008 [Gómez et al., 2013]. Childhood obesity has become a major challenge for public health around the world because it continues into adulthood increasing the risks of non-communicable disease later in life. In 2010 the WHO estimated that there are over 43 million children either overweight or obese around the world and 35 million of these children are living in low and middle-income countries [Joseph, 2017]. Overnutrition is also a health issue in Fiji's population as it is manifested by the increase in diabetes and heart diseases in Fiji. The rate of change of death from 2005 to 2016 for diabetes was 45.7% and 28.3% for ischemic heart disease [Institute for Health Metrics and Evaluation, 2015]. However, this is another area of study that can also be undertaken.

Malnutrition is a complex illness caused by several factors, and to be able to prevent or minimise it, adequate and nutritious food must be considered [Sah, 2004]. Over the years child health has been progressing and improving. However, malnutrition is still a public health challenge faced by developing countries. In 2011 a total of 6.9 million deaths was reported for children under the age of five and a third was attributed to malnutrition. Globally, 178 million children under the age of five suffer from stunting, 55 million from wasting and 19 million from premature deaths due to the exposure to risk factors of malnutrition [Bhutta and Salam, 2013]. In 2011 it was estimated that 165 million children were stunted worldwide, with the WHO African region indicating the highest prevalence of moderate and severe stunting [Skolnik, 2016]. Muller and Kranwinkel, (2005) stated that approximately 68% of children under five in developing countries are malnourished (31% underweight, 38% stunted and 9% wasting) [Müller and Krawinkel, 2005]. Fikadu, et.al (2014) added that malnutrition causes over 2 million deaths worldwide, which represents 35% of all deaths for children under five years [Fikadu et al., 2014]. The prevalence of malnutrition is high in Sub Saharan Africa and South East Asia and is a significant cause of deaths of Ghanaian children under the age of five [Bhutta and Salam, 2013, Fikadu et al., 2014, Aheto et al., 2015]. The global statistics of malnutrition is alarming and is prevalent in developing countries and is a health risk to children under the age of five. Children are vulnerable to malnutrition as they need quality and adequate amounts of food for their developing bodies. Koletzko, B, (2009) found that nutritional needs of children are significant as they require a substantial amount of energy for their growing body. Children energy needs are three times more per kilogram of body weight than the needs of adults, because of their metabolic requirements of growth [Koletzko, 2008]. Adults only need nutrients for physical activity and maintenance requirements of the body. Healthy infants rapidly develop in 4-5 months after birth thus requiring much energy for their developing body. The quality and the quantity of their diet determines the consequences of the development of their organs and tissues and their overall health. Nutrition affects the growth of the body and has chronic effects on the health status. People with cardiovascular diseases later in life were found to have a low birth weight in their first 12 months of life [Koletzko, 2008]. It is the reason this study looked at the prevalence of malnutrition of children under five in the Fijian context.

Malnutrition, as explained above, is a health risk that is affecting people in the world, especially in children. Skolnik, (2016) stated that only a minor percentage of children dying directly as a result of malnutrition. Malnutrition is a crucial risk factor for other diseases such as diarrhoea, pneumonia and measles that can cause death and around 45% of deaths from children under five are due to malnutrition-related illnesses [Joseph, 2017]. The UNICEF has created a framework shown in figure 1.6 outlining the underlying causes of malnutrition which includes the lack of access to household food, poor delivery of health services and inadequate care of women and children [Joseph, 2017]. The availability of food depends on factors such as the accessibility to

land to produce food for those in the rural areas and accessibility to money to purchase food for those in the urban areas. Child care practices affect the nutritional status of children, exclusive breastfeeding for the first six months and quality supplementary food must be appropriately administered. Accessibility to health care is also essential for children to get regular growth monitoring and immunisation to prevent illness and infections [Skolnik, 2016].

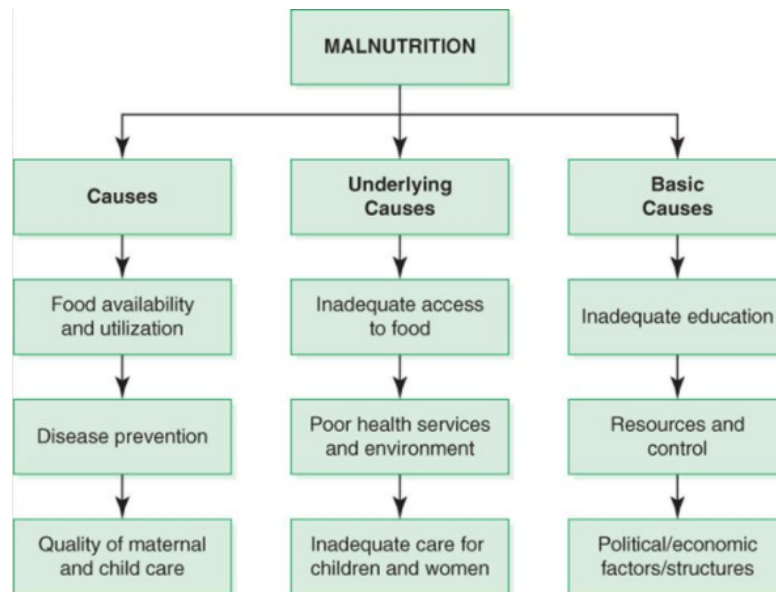


Figure 1.6: The figure shows the UNICEF Framework for the determinants of nutritional status . Malnutrition is a complex health issue, and the table summarises the various causal pathways of the illness.

[Joseph, 2017]

There are many causes and pathways of malnutrition discussed above. These studies have discussed many variables that can be responsible for malnutrition in the community, and they have not reviewed or considered the role of climate change related alterations in food production that can lead to undernourishment in vulnerable populations and countries. The goal of this study is to relate how climate change can be a pathway by influencing the availability and the utilisation of food. The Pacific Islands are also trying to cope with the issue of malnutrition within their own respective countries and may not be similar to other countries. It is essential to look at this pathway for Fiji as it is currently experiencing the effects of climate change through the variation in rainfall and increase in the frequency of extreme weather events. The variation in total rainfall leads to droughts and floods which destroys crops, has adverse impacts on water and sanitation which increases the chances of infectious disease outbreaks such as diarrhoea and typhoid fever. Damaged crops reduce supplies and increase demand, so prices increase leaving out many to forfeit nutritious fruits and vegetables making their household risk to micronutrient malnutrition. Episodes of diarrhoea and typhoid in children make them a risk to being malnourished through lack of appetite and loss of body fluids [Allen and Gillespie, 2001]. The increase in temperatures is ideal for pests and plant pathogens to ruin standing crops and cause food shortage also decreasing the supply and increasing the price. The importance of the study is to determine that the effects of climate change which is the increase in temperature, variation in rainfall and the frequency of extreme weather due to that variation are one of the contributing

factors to the prevalence of malnutrition in Fiji.

#### 4.1 The Status of Malnutrition in the Pacific Islands



Figure 1.7: *The figure shows the Map of the countries in the Pacific. Fiji is known as the hub of the Pacific as it is centrally located and is one of the developed countries in the Pacific.*

Malnutrition is prevalent in the Pacific Islands. The Pacific islands cover three regions – Melanesia, Polynesia, and Micronesia. Melanesian islands have volcanic mountains, fertile soils and abundant water supply. The Polynesian islands have a mixture of islands with volcanic mountains and coral atolls in contrast to the Micronesians who live on small coral atolls with limited space for agricultural activities and poor soil quality. There are contrasting health issues faced by the three regions in the Pacific. The Melanesian countries have high rates of infectious diseases and malnutrition, the Polynesians suffer from over-nutrition, and lifestyle disease and the Micronesians have under-nutrition for children and over-nutrition for adults [Paterson, 1994]. In the Federated States of Micronesia, 10% of preschool children suffer from stunting, and 13% underweight while adults are diagnosed with obesity, diabetes and hypertension [Hughes and Marks, 2009]. *Espiritu Santo*, a small island in Northern Melanesian country of Vanuatu reported 23% of children under five years are malnourished, even though the island has fertile land and abundant of fresh foods all year round [Williams et al., 1997]. Iodine, vitamin A and iron deficiency are prevalent in 16 Pacific Island countries ranging from a low of 10% to a high of 57%, mainly affecting women and children. The situation differs from country to country. In the Federated States of Micronesia, anaemia is prevalent among 38% of women and 33% of children [Hughes and Marks, 2009]. The Eastern Highlands of Papua New Guinea (PNG) recorded the high prevalence of stunting cases [Wand et al., 2012]. Malnutrition cases in PNG accounted for 36% of deaths amongst childhood hospital admission in 2012. The trend has been increasing over the years due to neglect, more emphasis on other diseases such as malaria [Aipit et al., 2014].

The Pacific Island countries are also vulnerable to malnutrition but not as significant as countries in Africa and Asia due to the landmass, population size, food security, accessibility to health services and vulnerability to climate change. However, malnutrition is an issue in some of the Pacific Island nations. The table 1.4 shows that the Solomon Islands have the highest proportion of the undernourished population with 8%, followed by Vanuatu and Kiribati at 8% between 2010 and 2012. The table also shows the comparison of the undernourished population of some countries in Asia and the Pacific [Weber, 2014].

Country	1990-92	2000-02	2010-12	% of change
Georgia	60.4	23.0	25.0	-58.6
Viet Nam	46.9	20.9	9.0	-80.8
Thailand	43.8	17.4	7.3	-83.3
Solomon Islands	23.0	14.0	13.0	-45.5
Samoa	13.0	5.0	5.0	-61.6
Vanuatu	11.0	8.0	8.0	-27.3
Kiribati	9.0	7.0	8.0	-11.1
Fiji	6.0	<5	<5	>-16.7

Table 1.4: *The table shows the prevalence of undernourished people in some countries in Asia and the Pacific. It is noted from the table that countries in the Pacific are facing the issue of malnutrition, even though there have been some improvements for Samoa, Vanuatu and Fiji. [Weber, 2014]*

## 4.2 Malnutrition in Fiji

The Fijian Ministry of Health annual reports does not divulge much information on the prevalence and the incidences of malnutrition in Fiji for the past years. The annual report of 2013 stated that the prevalence of malnutrition in children under five was 36.3% [Ministry of Health, 2014]. The annual report of 2015 indicated that the Lautoka Hospital in the western division recorded a decrease in 55% of the cases recorded in 2014. Malnutrition as a risk factor for combined death and disability recorded decrease of 19.4% for the percentage of change between 2005 and 2016 [Institute for Health Metrics and Evaluation, 2015]. It indicates that the risk of malnutrition to cause death and disability has decreased in Fiji over the eleven year period. Even though the threat has decreased, children and pregnant mothers are vulnerable to malnutrition which can affect their health status in the future. There were studies conducted that showed that there was a prevalence of malnutrition in Fiji. Research conducted in Tavua subdivision, on the western side of Fiji found that there was a prevalence of malnutrition amongst infants between birth and five years was at 40% from January 2010 to April 2012. The study further states that Fijians of Indian descents were malnourished due to the low birth weight of mothers and Indigenous Fijians malnutrition was due to the slow and poor quality of food during the weaning process [Atalifo et al., 2016]. The study shows that malnutrition is prevalent in Fiji, and there are differences in the malnutrition cases between the ethnic groups as shown in figure 1.8. The research shows the number children below the age of six months were less malnourished than those from seven months and above. The ethnic distribution of the cases below six months shows that more Indo Fijians were malnourished compared to the I Taukei and other races [Atalifo et al., 2016].

The high malnutrition in Indo Fijian babies is due to the high number of low birth weight as compared to the other two ethnicity. Low birth weight is a predictor of child survival and development, and low birth weight in Indo Fijians is due to poor maternal diet, lack of prenatal health service available and not accessing the available services [Schultz T. J et al., 2007]. In the seven months and over age category, the I Taukei children were more malnourished than the Indo Fijians and the other races [Atalifo et al., 2016]. The reason for the increase in malnutrition amongst I Taukei children after seven months was due to the delayed weaning process and late introduction of supplementary foods, together with the poor choices of supplementary foods given to children [Schultz T. J et al., 2007]. Malnutrition is prevalent in Fiji and is affecting children through the poor maternal health of mothers, not accessing prenatal and postnatal health services, slow weaning process of babies, and poor choices of supplementary diets. However, there is no explanation on the contribution of climate change effects as one of the risk factors for malnutrition.

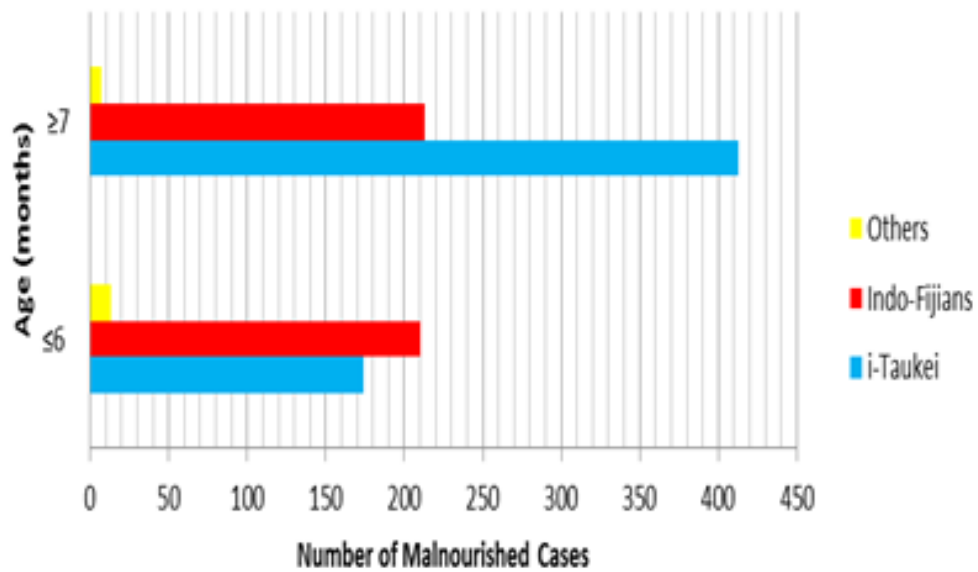


Figure 1.8: The figure shows the number of malnutrition cases according to age and ethnicity in Tavua Subdivision, Fiji. The Indo Fijian children are more malnourished than the I Taukei at below six months. In the age group above six months the I Taukei children are more malnourished than the Indo Fijian babies

[Atalifo et al., 2016]

## 5 Statement of the Problem

The Fijian Ministry of Health website [Ministry of Health Fiji, 2015] reported that malnutrition is the number one childhood killer in the country, this is an alarming statement coming from the health ministry. Fiji has the abundance of fresh fruits, vegetables, root crops, marine and aquatic food and yet reports of malnutrition and fatalities caused by malnutrition are

still happening. The recent update from the Institute of Health and Metrics Evaluation state that the observed mortality of children under five increased from 27.3% in 1990 to 37.8% in 2016 [Institute for Health Metrics and Evaluation, 2015]. There is no proper term used by the I Taukei people to refer to malnutrition as it was almost non-existent in the past. The term that medical personnel use when referring to malnutrition in the I Taukei language is “*mate ni kana vakaca*”, which means that there are insufficient calories and nutrients in the diet. A non-governmental organisation (NGO) Save the Children Fiji conducted a survey which revealed that 420 children under five years died from malnutrition in 2013 [Gibson, 2014]. This is an alarming statistics for a small country such as Fiji. This study determines if climate change is one of the factors associated with the increasing prevalence of malnutrition in Fiji.

Climate change causes variability in the weather due to the increase in greenhouse gases in the atmosphere which causes global warming. Scientists are still contemplating the effects of climate change on El Nino, but everyone knows that there is a steady increase in the ocean temperature. No one knows how it might affect El Nino. The IPCC has low confidence in what happen to ENSO but has high confidence that ENSO continues in the future [Pachauri et al., 2014]. The warming climate increase rainfall levels and the future ENSO either strengthen or weaken the rainfall patterns. Natural disasters such as cyclones, droughts and floods caused significant damage to the agricultural sectors in Fiji. There were two major floods in the Western Division in 2012 that caused \$FD16 million damages to the agricultural industry. It caused significant shortages of fresh fruits and vegetables in the region [Müller and Krawinkel, 2005]. The floods occurred during an intense La Nina phase where the SPCZ shifted southwards and was on top of Fiji, bringing with it rain bands [Hagos et al., 2014]. The flood was one of the many natural disasters to impact Fiji in the last decade, and there is proper documentation of the effect on the agriculture sector while the impact on health concerning malnutrition is limited. The United Nations Food and Agriculture Organisation issued a statement in the media that malnutrition cases were recorded in Fiji during that period, which was caused by shortages of vegetables, four months after category five *Cyclone Winston* hit Fiji in February of 2016 [Pacific Islands Report, 2016]. The effects of climate change are being experienced in Fiji as mentioned above and claims have been made after extreme weather that malnutrition cases rise. Can climate change be one of the factors responsible for the increase in the prevalence of malnutrition in Fiji through the increase in temperature and variation in rainfall and humidity levels which influence climate variability? Climate change related events are responsible for reduced crop and associated with increased risk of diseases that predispose people to malnutrition, and this is studied in the context of Fiji.

There was a study conducted in Fiji on climate change and health looking at infectious disease and potential early warning systems. Piloting Climate Change Adaptation to Protect Human Health (“PCCAPHH”) in their report has identified four priority climate-sensitive diseases in Fiji. The diseases are dengue, diarrheal disease, leptospirosis and typhoid fever. Thorough research has been carried out on these diseases in Fiji. The PCCAPHH analysed the monthly communicable disease notifications between 1995 and 2009 using Poisson Regression models [World Health Organization, 2015]. The results showed a positive correlation between monthly temperature and rainfall with dengue fever, and there were ten outbreaks of dengue in the Pacific including Fiji during the La Nina season. Diarrhoea in children was positively associated with intense rainfalls, and increased temperatures and leptospirosis outbreaks usually were experienced after cyclone [World Health Organization, 2015]. The results of the above study show that climate change has an effect on the infectious diseases in Fiji. This study aims to fill the gap on the effects of climate change effects on the prevalence of malnutrition in Fiji.

There is a need for further studies on the other four health burdens which include malnutrition,

climate change induced NCD related illness, psychological impacts of extreme climatic events, and limited accessibility to health services after disasters. Research on the relationship between climate change and malnutrition were conducted in Africa and Asia, and there has never been any similar kind of study conducted in Fiji. It is one of the first studies of its kind in investigating the association between climate-related variables and the prevalence of malnutrition in Fiji. The proposed research is in line with the Fijian Ministry of Health and Medical Services Climate Change and Health Strategic Plan 2016-2020. It meets the objectives of component 5 of the plan. The fifth component provided for resilience building and applied research on how local conditions are affected by climate change. Using the available surveillance data to understand the vulnerability of the population to climate change. The research findings to be utilised by policy makers and decision makers in addressing health issues related to climate change [Ministry of Health and Medical Services Fiji, 2016a].

Climate change has been happening for hundreds of years through external and internal means. Human interference has accelerated the rate of climate change, where excessive carbon dioxide, methane and other greenhouse gases were emitted into the atmosphere that leads to global warming. Climate change causes variability in the daily weather patterns meaning that summer days be warmer and nights less cold, there be more intense rainfall during the rainy season or there be less than average rainfalls. Weather is not climate, but underlying changing climate is responsible for the change in weather patterns. The increase in global temperature reduces the number of tropical cyclones in the Pacific but increases its strength and the intensities of rainfall associated with the cyclone. High temperatures in the atmosphere contain more water vapour and increasing chances of rainfall. Increase in temperatures melts ice from mountains and glaciers increasing the sea level. The effects of climate change on the weather patterns alter salinity of seawater, loss of habitats, loss of coastlines, and storm surges which are associated with reduced crop production as crops are principal subsistence of diet, therefore expectedly the prevalence of malnutrition increase over a decade in Fiji. This study is using a quantitative assessment and a qualitative approach, they are done independently but complement each other in the study. The quantitative assessment is looking at the time series analysis of the climate variables and malnutrition and also use a smoothing moving average and decomposition of time series to determine the trends of climate and malnutrition variables. The qualitative approach review the existing literature on other factors associated with malnutrition was done separately with themes such as extreme climatic events, policies and malnutrition, socioeconomic factors and other factors of malnutrition. The qualitative aspect of the study complements the main findings of the study. The issues identified above raises questions on what is the association between the climate-related variables and the prevalence of malnutrition? What is the trend of malnutrition? Is there a link between the trend of the available variables and malnutrition?



## Chapter 2

# Literature Review

### 1 Introduction

The chapter begins with the facts and figures on anthropogenic climate change and its trend and projections. It further explains the effect of the increase in global temperatures on public health. The second subsection describes malnutrition as a complex and multidimensional issue with many associated factors, and the types and global trends of malnutrition. The section further describes how climate parameters are affecting the prevalence of malnutrition. The climate of the Pacific Islands, as well as the prevalence of malnutrition in the islands, are discussed, and lastly, Fiji's climate and malnutrition status are discussed along with the gaps identified in the literature that will be filled when conducting this study.

#### 1.1 Climate Change

Changes in climatic patterns have occurred naturally in the past, however the current circumstances of climate change are unique, due to the influence of human activities. Humans have accelerated the effects of climate change through the burning of fossil fuels for agriculture and development goals which has increased global temperatures. The IPCC 5th Assessment Report stated that human interference on the climate is clear, and recent trends have shown significant increases in anthropogenic emission. The report adds that there is a significant relationship between the increasing carbon dioxide emissions and the projected temperature trend up to 2100 [Pachauri et al., 2014, McMichael, 2003]. Anthropogenic activities along with new gases such as chlorofluorocarbons (CFC's) which are added to the environment increase the naturally occurring gases such as carbon dioxide [Latif et al., 2009]. Combustion of fossil fuels and forest fires, methane coming from agricultural activities such dairy livestock, livestock breeding, oil extraction and also from sewage treatment plants and halocarbons produced by humans are the main produces of greenhouse gases [McMichael, 2003]. The burning of fossil fuel and industrialisation contributed to 78% of anthropogenic greenhouse gas emissions produced between 1970 and 2010. Anthropogenic greenhouse gas emission recorded a significant increase between 2000 and 2010. It was an increase of 10 *Giga* tonnes of carbon dioxide of which 47% was from energy, 30% from industry, 11% from transport and 3% from building [Pachauri et al., 2014, Edenhofer et al., 2014].

The IPCC Special Report on Emissions Scenarios (SRES) modelling predicted that the concentration of carbon dioxide by the year 2100 would be 90% to 250% above the 1750 concentrations. When the effect on the land and the ocean is accounted for (reduced uptake of carbon dioxide on the land and the ocean), the amended projections is 75% to 350% above the 1750 concentrations. The implementation of mitigation measures like reforestation will decrease the concentration of the carbon dioxide concentration by 40 to 70ppm [Stocker, 2014]. According to the IPCC climate change synthesis report, the combined land and ocean temperature between 1880 and 2012 showed an average increase of 0.85 °C. Climatologist has also found that in the twenty year period between 1993 to 2003, the global mean temperature increased at a rate of  $0.14 \pm 0.06$  °C per decade [Pachauri et al., 2014, Morice et al., 2012, Edenhofer et al., 2014]. However, there are some different readings between the predicted and the actual temperature. Fyfe, et al (2013) found that observed global warming is significantly lower than the predicted models. The predicted increase in the average global temperature is  $0.3 \pm 0.02$  °C per decade on the same period from 1993 to 2003. The variation in the two readings is due to a combination of several factors such as errors in external forcing, model response and internal climate variability [Fyfe et al., 2013]. Even though climate change has been occurring naturally in the past, the influence of humans has accelerated the change. The world has been warming at an alarming rate faster than ever before, and this has influenced variation in weather patterns. Years of data collection and analysis by scientists under the IPCC, which has released five assessment reports, have proven that climate change is a reality. There are still some grey areas such as predicted temperature readings which do not correspond with the actual temperatures, however.[Edenhofer et al., 2014, Pachauri et al., 2014].

The increase in global temperature has been projected to cause changes to the climate system. These changes include the increase in the frequency and the duration of heat waves and rainfall. The oceans will continue to get warmer and more acidic, and the global mean sea levels will continue to rise [Pachauri et al., 2014]. One of the significant effects of the increase in temperature is the melting of ice from ice sheets in Greenland and Antarctica with the rates of ice loss extremely high between 2002 and 2011. Satellite and surface-based observations for the past 46 years have shown that sea ice in the northern hemisphere has shrunk. The situation is worse in the summer as the rate of decrease ranges from 9.4 to 13.6% per decade [Edenhofer et al., 2014, McMichael, 2003, Pachauri et al., 2014]. The loss of ice has contributed to sea level rise through the 20th century. The other factor that can increase sea level is the thermal expansion of the ocean due to warming. According to the IPCC 5th Assessment Report, average sea levels rose by 0.12 to 0.21 meters between 1901 to 2010, and the forecast is that by the end of the 21st century, 70% of the coastline is expected to experience sea level rise within  $\pm 20\%$  of the global average. The fluctuation in ocean circulation causes the variation in sea level rise in different regions of the world. The rate of sea level rise in the Western Pacific region is three times more than the world average, as compared to the Eastern Pacific region which is closer to zero [CSIRO et al., 2011, Nicholls and Cazenave, 2010, Pachauri et al., 2014, Stocker, 2014]. The report also stated that there would be variation in rainfall levels around the world; there will be places where there will be more frequent and intense rainfall, and in some areas below normal rainfalls, resulting in droughts and floods. Increase in global temperatures will also affect the duration and the intensity of extreme climate events, such as flooding, droughts, heat waves and cyclones [Pachauri et al., 2014, CSIRO et al., 2011, Stocker, 2014]. The IPCC reports on the effects of global climate change are evident in our local environments. These include sea level rise, which is a threat for the low lying islands of the Pacific and other parts of the world, the increases in the intensities of heat waves in the Northern hemisphere, and increases in the severity of storms in the Pacific associated with high variability in rainfall patterns.

Variations in the global temperature will have a significant impact on public health. High temperatures have caused many fatalities around the world as people succumb to the intense heat [Patz et al., 2005]. Ahasan, (2008) and O'Dwyer, et al, (2016) state that high temperatures will be more frequent during the summer at high latitudes and increase the risks of heatstroke, such as the South Asian heat waves which caused a high mortality rate amongst day workers and the elderly [Ahasan, 2010, O'Dwyer et al., 2016]. Europe recorded the hottest summer in 2003 with temperatures rising to 3.5 °C above average. In August 2003, approximately 22,000 to 45,000 heat-related death reports came from across Europe [Patz et al., 2005]. Ahasan, (2008) and McMichael, (2013) also added that most of the reported deaths were from people with existing medical conditions like respiratory and cardiovascular illnesses and the senior citizens [Ahasan, 2010, McMichael, 2003]. In Australia, during hot days, the number of emergency hospital admissions increases from people with existing medical conditions [Hashim and Hashim, 2016]. Temperature also varies between urban and rural areas. Urban areas experience more heat than rural areas due to the urban heat effect, where there are numerous heat-retaining surfaces like concrete and asphalt which increases ambient air temperatures [Ahasan, 2010, Luber and McGeehin, 2008]. The combined heat from the urban heat effect and the low ventilation caused by skyscrapers creating urban canyons adds to the higher temperatures already caused by climate change. The concrete and the asphalt absorbs heat during the day and radiates it at night increasing the night time temperature. The urban areas, through the urban heat effect, have 1°C to 6°C more air temperature readings than the rural areas [Luber and McGeehin, 2008, Vose et al., 2004]. The rise in temperature is affecting people with health conditions as people try and adapt to this change. As temperatures are expected to increase more in the urban areas, the number of fatalities is likely to increase as more people live in urban areas in both developed and developing countries. Increases in temperature also increase the geographical ranges of disease vectors. Ahasan, (2008) and McMichael, (2013) also stated that warmer temperatures significantly increase the risk of vector-borne diseases outbreaks as it enhances the replication of the vector and reduces maturation period [Ahasan, 2010, McMichael, 2003]. Malaria has claimed 1 to 2 million lives annually, and recent modelling exercises have predicted that malaria will increase by 5 to 7% by 2100 [Lindsay and Martens, 1998, Tanser et al., 2003].

The increase in temperatures from global warming causes variation in daily weather patterns. Increase in temperatures increases the intensities of storms and precipitation. In some areas, there will be more than average rainfall while other places will experience less than average rainfalls. The IPCC reported that mid continental droughts would reduce the agricultural yield in tropical and subtropical regions. Crops that are reaching their temperature tolerance level in Africa, South America and in the tropics will be the most vulnerable [Pachauri et al., 2014]. The WHO ranks malnutrition as one of the most significant global health burden associated with climate change [Franchini and Mannucci, 2015]. The Food and Agriculture Organisation (FAO) reported that there are 790 million people in developing countries who are suffering from malnutrition and climate change is expected to worsen the food security and malnutrition status of countries and regions that already have malnourished populations and food shortages [McMichael, 2003, Singh and Purohit, 2014]. Climate-sensitive diseases are a growing concern for most countries around the world, as there are more reported fatalities from this climate-related illness. Hasim, et al (2016) stated that climate-related fatalities accounted for 3.5 million deaths from malnutrition, 1.8 million from diarrhoea and 800,000 from respiratory illnesses [Hashim and Hashim, 2016]. The WHO further estimated that continued increase in warming would contribute to the additional deaths of 38,000 elderly from heat waves, 48,000 children from diarrheal diseases, 60,000 from malaria and 95,000 from malnutrition

[Franchini and Mannucci, 2015]. Extreme seasonal changes is a concern for people in parts of Africa, Latin America and Asia as they experience an increase in droughts and floods, loss of biodiversity and the risk of food security [Patz and Kovats, 2002]. Floods and droughts increase the vulnerability of people in developing countries to physical injury, water-borne diseases and malnutrition [Haines and A, 2004] [Wakuma Abaya et al., 2009]. Abaya, et al, (2009) in their study on the effects of flooding found that it caused a 20% reduction in crop production. The study could not relate the effect of flooding on the nutritional status but stated that the shortage of food increased the risk of malnutrition in Ethiopia. This study will look at the association between climate change and malnutrition in the Fijian context.

## 1.2 Nutrition

Malnutrition is complex and, and as such, no single factor can be identified as the cause. Gomez, et al (2013) stated that undernourishment is defined as the insufficient calorie and protein intake to meet the requirements of a person body and is a contributing factor to adverse health consequences measured by anthropometric indicators [Gómez et al., 2013]. There are two main types of malnutrition classification, protein-energy malnutrition and micronutrient deficiency diseases. The protein-energy malnutrition is the result of deficiencies of all nutrients, and micro-nutrient deficiency is deficiency from specific nutrients [Bhutta and Salam, 2012]. Stunting and wasting are two terms that are globally used to describe the prevalence of malnutrition in children [Victoria, 1992]. Stunting and wasting are severe forms of malnutrition, and the two forms of malnutrition are closely related and sometimes co-occur in a community or population especially in children. It can affect a single child simultaneously and increases the risk of vulnerability to other infectious diseases [Briend et al., 2015]. Wasting is the difference in weight and height which causes thinness and stunting is the difference in height to the child's age, and it is an indicator of a long-term or chronic malnutrition. It develops early in children between the age of 6 months and two years. It is usually due to early weaning, lack of protein in the diet, delayed in the introduction of additional foods and natural infections. It is considered to be an acute situation, with weight loss being recent. Stunting is often associated with frequent exposure to a severely restricted economic environment, inferior sanitation, poor nutrient intakes and exposure to diseases [Martorell et al., 1994, Allen, 1994, Gómez et al., 2013]. Children with severe cases of protein-energy malnutrition develop oedema. Oedema is the build-up of fluids in the tissues, especially near the feet and legs. The children may not lose weight due to the extra fluids in the body which compensate the loss of fat and muscle tissue, causing children to appear bloated and fat [London School of Hygiene and Tropical Medicine, 2009]. The disease is also known as *kwashiorkor*, which originates from Ghana, which means the condition the baby develops when it is displaced from the mother due to pregnancy [Müller and Krawinkel, 2005]. The other disease is *marasmus* which is the same as *kwashiorkor* but this time it produces thinness without oedema [London School of Hygiene and Tropical Medicine, 2009]. It has been linked to babies using contaminated feeding bottles, especially in the urban areas [Müller and Krawinkel, 2005]. In this study, the prevalence of the indicators of malnutrition which falls under both the categories of protein-energy malnutrition and micronutrient deficiency is examined.

Micronutrient deficiencies affect two billion people globally; 740 million with iodine deficiency, including 300 million with goitre [Müller and Krawinkel, 2005]. Iodine deficiency affects 13 percent of the global population with more than 740 million suffering from goitre, and more than 2 billion people are reported to be suffering from iodine deficiency disorder [Bhutta and Salam, 2013]. Bhutta and Salam, (2013) and Muller and Krawinkel, (2005) stated that another 20 million developed brain damage during foetal development due to maternal-foetal iodine deficiency and about

2 billion people suffer from zinc deficiency. Zinc deficiency affects 2.8 million pre-school children in more than 60 countries [Müller and Krawinkel, 2005, Bhutta and Salam, 2013]. Muller and Krawinkel, (2005) added that one million children have anaemia or iron deficiency and 250 million have a vitamin deficiency. Individuals with iron deficiency develop anaemia, fatigue, reduced growth and physical strength, while those with iodine deficiency suffer from goitre, constipation and reduced growth [Müller and Krawinkel, 2005]. Pregnant women, infants, preschool children and teenagers are susceptible to anaemia [Paterson, 1994]. The lack of vitamin A causes night blindness, immune deficiency, increases children's vulnerability to disease and zinc deficiency causes complications during pregnancy, and also increases children's vulnerability to disease [Müller and Krawinkel, 2005]. Anaemia is a form of micronutrient deficiency due to the lack of iron in the blood. Anaemia or low haemoglobin levels (Hb) in the blood leads to adverse mental health effects, causing weakness and low self-esteem [Balarajan et al., 2011, Stevens et al., 2013]. Anaemia is the decrease in the quality of red blood cells, followed by a reduced haemoglobin level or changes in the red blood cell levels which hinders the delivery of oxygen to the body tissues [Kassebaum et al., 2014, Syed et al., 2016]. Age, gender, pregnancy status and ecological factors, such as altitude and smoking are different characteristics that affect anaemia in a person [Balarajan et al., 2011, Syed et al., 2016]. Pregnant women with anaemia are at risk of maternal mortality and delivering low birth weight babies [Steer, 2000, Stevens et al., 2013]. The global status of haemoglobin in women and children has been increasing resulting in the decrease in the prevalence of anaemia [Stevens et al., 2013]. In 2011, the WHO estimates around 800 million women and children are anaemic, while proper iron intake could reduce this by 42% to 50% in children [Organization, 2015, Stevens et al., 2013]. There are other causes of anaemia that include exposure to infectious and parasitic diseases such as malaria, HIV, lymphatic filariasis and hookworms, and the lack of specific vitamins in the body [Syed et al., 2016]. This study will examine the severe malnutrition which comes under the stunting and wasting category, and underweight, which is a combination of stunting and wasting, and also growth faltering, since childhood measurements are done in weight and age, and also anaemia which is a form of micronutrient deficiency.

Climate change is increasing the risk of hunger and undernutrition in certain parts of the world. The rise in temperature affects the global weather and indirectly affects food production and leads to malnutrition. The effect of climate change on nutrition security is through various pathways such as

“food security, livelihoods, household food access, maternal and child care, health, water and sanitation”

together with other social factors that decide nutrition security [Parry et al., 2007, Tirado et al., 2013]. Changes in temperature are expected to affect agricultural output and scarcity of crops. The variation in temperature will significantly affect the already low agricultural production which will, in turn, cause an increase in the food prices, where vulnerable groups such as children, pregnant women and older generation would be susceptible [Tirado et al., 2013, Parry et al., 2009, Parry et al., 2007]. However, there is insignificant evidence on the direct link between the effects temperature variation and malnutrition. A study conducted by Hagos, et al. (2014) found that temperature has an insignificant effect on child stunting and underweight. Variability in the temperatures of the three zones (Highlands, Midlands and Lowlands) in Ethiopia was recorded whereas the lowlands had higher temperatures than the other two zones. The Highlands and Midlands had a higher prevalence of stunting, wasting and underweight than the plains. Statistical analysis confirmed that stunting, wasting, moderate and severe low weight are poorly related to temperature in all the three zones. The paper further states that the climate pro-

foundly influences stunting (which is low height for age) without taking into consideration the child's livelihood. The study concluded that higher or increased temperature does not affect the malnutrition status of children [Hagos et al., 2014]. Grace et al (2012), supported it, in their study found no significant relationship between child stunting and temperature, but found significant associations between rainfall levels and various social factors with childhood stunting [Grace et al., 2012]. Singh, et al (2006) challenged the previous study findings related to different levels of malnutrition in a country depending on the location and the livelihood of the children. In desert areas, pre-school children suffer from protein-energy malnutrition and vitamin deficiencies more than those in non-desert areas and other parts of rural India. Children in deserts are exposed to high heat intensity and harsh environmental conditions, limiting their food sources and food intake. Prolonged drought due to climate change further adds burden to their existing livestock and quantity of harvests [Singh et al., 2006]. It is a common understanding that increases in temperature will be experienced during droughts because the increasing temperature increases evaporation and dries up the environment. The second theory is that the reduction in rainfall during the droughts reduces cooling due to evaporation and increases the temperature. A research study was conducted to determine which of the two theories is correct by using climate variables (temperature and rainfall) together with incoming and outgoing long wave and short wave radiation in various sites across Australia, the US and Brazil. The result supported the second theory and analysis showed that temperature increases during droughts vary due to the variation in the radiation from an increase in temperature caused by carbon dioxide [Yin et al., 2014]. Temperature might not have a direct impact on malnutrition, but its effect on the environment contributes to malnutrition. Two studies conclusively concluded that there is an association between drought, childhood wasting and micronutrient malnutrition, especially vitamin A deficiency. Chotard (2011) demonstrated that years of drought in countries in the Greater Horn of Africa is linked with childhood wasting. The dry season ('hunger season') or the first half of the year, recorded a high prevalence of wasting. Arlappa (2009), in their study, found that children residing in drought-affected areas had a higher prevalence of vitamin A deficiency. In both the studies the frequency, intensity and the duration of the drought caused disruptions in the availability and accessibility of food which accounted for the high prevalence of wasting and micronutrient deficiency [Chotard et al., 2010, Arlappa et al., 2009]. These studies show that drought, which is associated with heat or temperature, has a significant effect on the production, availability and consumption of food which contributed to child malnutrition.

Variations in rainfall patterns and trends across the world would have significant effects on the environment and also indirectly affects human health. Meshram, et al (2012) found in their research that prevalence of malnutrition in preschool children (stunting, wasting and underweight) was significantly higher during the rainy season as compared with the incidence during the summer and the winter months. The rainy season was regarded as the lean period as it was a time of harvesting, so there were limited food grains available at home [Meshram et al., 2014]. Grace, et al (2012) in their Kenyan study, found that there was a definite relationship between the levels of precipitation and child stunting. Rainfall is one of the significant components of climate change, and other factors contribute to the prevalence of stunting during the rainy season. The study also found that the significance of the relationship is on seasonal rainfall and not on the variability of the rainfall. These other factors include livelihood, mother's education level, availability of water supply (exposure to illness) and floor type ( a measure of household wealth) [Grace et al., 2012]. Hagos, et al, (2014) agreed with the previous literature, which demonstrated a high correlation between severe wasting and precipitation levels. There was a high incidence of underweight in the highlands during very low or very high rainfall. Cases of malnutrition were determined by the amount of rainfall during the growing season, as low rainfalls affect crops productions and avail-

ability. Precipitation levels also vary between the different living zones (Lowlands, Midlands and Highlands). Therefore the vulnerability of children depends on where they live and the variability of rainfalls during the growing season [Hagos et al., 2014]. Tirado, et al (2013) further stated that changes in rainfall patterns and levels would reduce food production [Tirado et al., 2013]. In a study in 2012, Jankowska, et al (2012) demonstrated that temperature and rainfall trends had significant effects on stunting especially in the rural areas [Jankowska et al., 2012]. He concurred with Hagos, et al (2014) who shows that there is a correlation between stunting and underweight with the geographical locations of people (urban and rural), the population density and the livelihood zones (pastoral, rice or plateau). Anaemia and underweight are short-term malnutrition indicators and may not necessarily determine the actual nutritional status as they can be responding to climatic seasonal flux and shocks [Hagos et al., 2014].

### 1.3 The Pacific Islands

The natural climate variability in the Pacific is due to climate phenomena such as the SPCZ, the ITCZ, ENSO, La Nina and El Nino. Pacific Island countries experience a warm, humid climate. They have two seasons, a warm wet season from April to November and a cold, dry season from May to October. The wind bands are the South Pacific Convergence Zone (SPCZ), the Inter-tropical Convergence Zone (ITCZ) and the Western Pacific Monsoon (WPM) and the three large wind bands cause variability in the seasons. The strength of the wind determines the rainfall and the seasons in the Pacific islands. The ITCZ lies north of the equator and affects the Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau and Papua New Guinea, and the SPCZ has a significant impact on the climate of Fiji, Cook Islands, Niue, Solomon's, Vanuatu, Tonga and Samoa [Keener, 2013, CSIRO et al., 2011]. Salinger, (2005) described El Nino Southern Oscillations (ENSO) as a natural climate variability that happens every 2 to 7 years. It is a significant global tropical variability with global consequences. ENSO is the trade winds of the Pacific blowing from the south-east and fluctuating between the El Nino and the La Nina phase. During an El Nino year, the trade winds weaken, and the warm waters of the Western Pacific shift eastwards towards the Central Pacific and South America. The warm waters take the low pressure with it, so the central and the west coast of South America receive more than usual rainfall. The Western Pacific will have an abnormally high-pressure system associated with dry and drought conditions [Salinger, 2005]. The El Nino of 1997 and 1998 caused widespread drought throughout the Western Pacific and parts of the Central Pacific. The countries of Vanuatu, New Caledonia, Fiji, Tonga, Southern Cooks and French Polynesia have received a significant reduction in average rainfall [Raj et al., nd]. The opposite of these occurrences is a La Nina year. During a La Nina year, the south-east trade winds strengthen and push the warmer waters far west of the Pacific, causing the countries located in the west of Pacific to have more than average rainfalls. El Nino and La Nina affect the SPCZ, during the La Nina years. The SPCZ moves further south from the equator and causes high-intensity rainfall in the islands south of the equator. During the El Nino years, the SPCZ shifts towards the equator taking the rain bands with it and countries south of the equator receive less than average rainfalls [CSIRO et al., 2011].

ENSO is measured using the Southern Oscillation Index (SOI) which represents the changes in the sea surface temperatures between Darwin, Australia and Tahiti. An active reading determines a La Nina year, and a negative reading indicates an El Nino year [Salinger, 2005]. El Nino and La Nina are natural variabilities, the trend in 1990 to 1995 recorded a weak El Nino but no La Nina. The prolonged El Nino of 1982-83 and 1997-98 is considered more than a natural variability [Trenberth and Hoar, 1996]. This natural climate phenomenon causes much variability in the

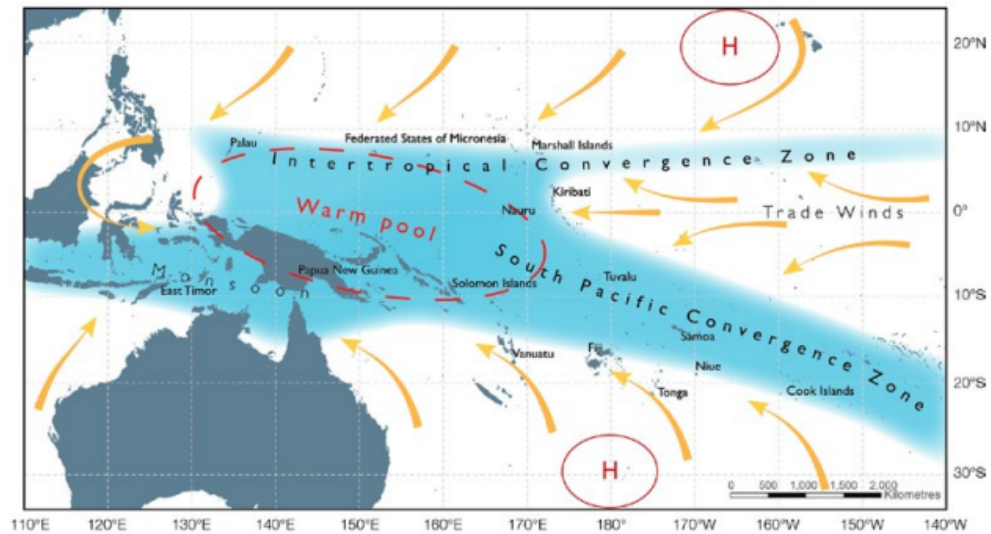


Figure 2.1: The figure shows natural climate phenomenon occurring in the Pacific Region, and this is a typical climate during November to April. The arrows represent the surface winds, and the blue shading represents the rain bands or the low pressure, and the H represents the high pressure. The red circle represents the Pacific Warm Pool [CSIRO et al., 2011]

weather around the Pacific as explained in the preceding paragraph. The increase in global temperatures due to global warming has added a further burden to the people in the Pacific Islands as they try to adapt to the changing climate. The vast ocean mass and the geographical makeup of many of the islands makes the Pacific Islands more vulnerable to the effects of climate change compared to other parts of the world.

The increase in temperature in the Pacific is now an accepted phenomenon, and Pacific Islanders are experiencing its effects. The rise in temperatures in the Pacific has many variabilities compared to other regions of the world due to the variability is the geographical locations of the islands. The countries located near the equator have a constant temperature throughout the year as do states situated farther south. One of the nations, Tonga has temperature variations of 6 °C between the minimum and maximum temperature through December to March [CSIRO et al., 2015]. A study conducted by Kumar, et al (2013) on the temperature trend in Fiji showed that maximum and minimum temperatures are increasing from 0.08°C to 0.23°C per decade. These were observations from more than ten stations across the country taken over the last 78 years. There was a slight increase in the temperature trend for maximum temperature from 1989 to 2008 increasing to 0.18°C to 0.69°C per decade [Kumar et al., 2013]. The PCCSP global emission modelling has predicted that temperature in the Pacific is expected to increase to 3 degrees Celsius by 2090 [CSIRO et al., 2011]. Temperature has been increasing all over the Pacific, and the Western North Pacific has recorded an increase in the maximum and minimum temperatures in the past 60 years. The Central and South Pacific have shown general warming trends since the 1950's [CSIRO et al., 2011, Keener, 2013]. Even though the temperatures are increasing in the Pacific, the projected increase will be less than the global average [Joshi et al., 2008, Dommenget, 2011]. The increase in temperatures in the Pacific has also altered the characteristics of ENSO, increasing the severity of La Nina and El Nino events



[Walsh et al., 2012]. Even though many variabilities influence the increase in temperatures in the Pacific, the fact that it is increasing is unarguable. The rise in both the maximum and the minimum temperatures is a clear indication of the increase which has occurred over an extended period. This study looks at the maximum and minimum temperatures for a decade from 2006 to 2016 to determine if it also follows a similar trend stated by other researchers.

The rise in global temperatures causes sea level rise, variation in rainfall patterns and extreme weather events in the Pacific. Sea level rise increases the risk of coastal erosion and flooding in atoll islands and those communities and settlements living near the coast. According to IPCC, (2014), the number of coastal inundation events will increase as storm surges are predicted to become more extreme due to sea level rise [Pachauri et al., 2014, Stocker, 2014]. The Western North Pacific recorded the highest rate of sea level rise during 1993 to 2010. The unusually high sea levels are due to fluctuations in the trade winds linked to the Pacific Decadal Oscillation (PDO) and low frequency of the Southern Oscillation Index (SOI) [Feng et al., 2010, Keener, 2013]. The IPCC 2014 synthesis report added that the sea level rise would vary across regions due to variations in ocean circulations, changes in wind and air pressure, and the flow of air-sea heat and freshwater. Recordings from 1993 have shown that rates of sea level rise in the Western Pacific are three times more than that of the world average [Pachauri et al., 2014, Timmermann et al., 2010]. Sea level rise readings taken by satellite near Fiji since 1993 showed it to be 6mm above the global mean of  $3.2 \pm 0.4$  mm per year [CSIRO et al., 2011]. The location of the Fiji Islands in the South Western Pacific makes it vulnerable to sea level rise, especially for its low lying islands, atolls and coastal communities. The amount and the distribution of rainfall within the Pacific is highly variable. The Central Pacific is getting drier, and the South Western Pacific is getting wetter due to the natural climate variability in the past 30 years [Feng et al., 2010, CSIRO et al., 2015]. Salinger, et al (2001) stated that rainfall variability is associated with ENSO while McCarthy, (2001) and Follard, (2002) added that the changes in the SPCZ and the ITCZ are consistent with the variability in rainfall patterns in the Pacific [Pinstrup-Andersen, 2009, Kuleshov et al., 2014, Organization, 2014]. The rainfall patterns in the Pacific are strongly determined by natural climate variability. However, there are no clear trends to determine that it is affected by global warming [CSIRO et al., 2011]. Projections from the ABM and the CSIRO indicate that rainfall is expected to increase in countries near the SPCZ and the ITCZ. Light and moderate rainfall days are expected to increase near the equator, extremely high-intensity rainfalls that happen once every twenty years are expected to occur four times in 20 years by 2055 and seven times by 2090 [CSIRO et al., 2011].

Tropical cyclones, droughts, floods, storm surges and coastal flooding are becoming a common event experienced by Pacific Island Countries. Tropical cyclones form when the ocean surface is warm, and the temperature gradient in the atmosphere is intense. As the climate warms, the difference between the temperature at the surface of the ocean and the temperature in the atmosphere decreases, causing a decrease in the expected number of cyclones [DeMaria et al., 2001, Field, 2012]. The rising temperatures increase the intensity of cyclones with high wind speeds and high-intensity rainfalls during cyclones. The warm surface waters provide a large pool of energy where the cyclone draws its strength. There will be fewer cyclones expected, but it will increase in intensity and strength due to climate change, and there will also be high-intensity rainfall associated with the cyclones [Emanuel, 2000, Wing et al., 2007]. It is evident in the increasing severity of cyclones affecting the Pacific islands recently, as seen in the category five cyclones Pam in 2015 and Winston in 2016. Floods and droughts in the Pacific are influenced by the ENSO, as it determines the locations of the Convergence Zones. The floods in Fiji in 2012 was due to the moderate La Nina and a tropical disturbance and the drought in Tuvalu in 2011 was due to the strong La Nina [Null, 2018, Office, 2012, Kuleshov et al., 2014].

Various locations in the Pacific experience different effects of El Nino and La Nina as in the case of Fiji and Tuvalu. The figure 2.2 shows how each country in the Pacific is affected by El Nino and La Nina

Country	Region	El Niño	Extreme El Niño	La Niña
Cook Islands	North	Wet	Wet	Dry
	South	Dry	Very dry	Wet
Federated States of Micronesia	West	Dry Lower than normal sea level	Very dry Lower than normal sea level	No consistent impact on rainfall Higher than normal sea level
	East	Lower than normal sea level	Dry Lower than normal sea level	Wet Higher than normal sea level
Fiji		Dry	Very dry	Wet
Kiribati	Gilbert Islands	Wet	Dry	Dry
	Line Islands	Wet Higher than normal sea level	Wet Higher than normal sea level	Dry Lower than normal sea level
Marshall Islands	North	Lower than normal sea level	Lower than normal sea level	No consistent impact on rainfall Higher than normal sea level
	South	Lower than normal sea level	Very dry Lower than normal sea level	Dry Higher than normal sea level
Nauru		Wet	Dry	Dry
Niue		Dry	Very dry	Wet
Palau		Dry Lower than normal sea level	Dry Lower than normal sea level	Wet Higher than normal sea level
Papua New Guinea		Lower than normal sea level	Dry Lower than normal sea level	No consistent impact on rainfall Higher than normal sea level in the north
Samoa		Dry	Dry Lower than normal sea level	No consistent impact on rainfall Higher than normal sea level
Solomon Islands		Dry Lower than normal sea level	Dry Lower than normal sea level	Wet Higher than normal sea level
Timor-Leste		Dry	Dry	Wet
Tonga		Dry	Very dry	Wet
Tuvalu		Wet Lower than normal sea level	Wet Lower than normal sea level	Dry
Vanuatu		Dry	Dry	Wet

Figure 2.2: The figure shows the effects of El Nino and La Nina in each country in the Pacific. There are different effects experienced in countries when exposed to the same climate anomaly, for example, La Nina is wet for Fiji and dry for Tuvalu [CSIRO et al., 2015]

Extreme weather events cause loss of public infrastructure especially the water and sewage facilities, which increases the risk of waterborne illness and other associated communicable diseases [CSIRO et al., 2015]. Climate and weather have always had a significant impact on the health and well-being of humans. The Cook Islands, Nauru, Niue, Solomon Islands and Vanuatu have the highest priority climate sensitive cases for heat-related illness in the Pacific. There is current research being conducted in Fiji to determine the association between increasing temperatures and mortality. In the Solomon Islands, there is current research on the relationship between malaria and temperature, as there is an assumption that there is an ideal temperature span for malaria to thrive [World Health Organization, 2015]. Modelling exercises suggest that due to

climate change, more regions will have a favourable climate for malaria vectors to thrive, increasing the risk of outbreaks and exposure [Caminade et al., 2014]. The water security in countries located on atolls such as Kiribati, Tuvalu, Nauru and Tokelau are vulnerable to the effects of climate change, as these countries depend on rainwater and freshwater aquifers for drinking. The intrusion of seawater from sea level rise into their water sources creates health implications, such as increasing hypertension and risks to infants and expectant mothers [Khan et al., 2011]. Ciguatera fish poisoning which is caused by consuming reef fish that contains toxic dinoflagellate organisms has high incident rates in the Pacific. The increase in the sea surface temperatures and ENSO cycles has contributed to the increase in ciguatera fish poisoning cases over the years [Skinner et al., 2011, Hales et al., 1999]. These are the some of the health effects in the Pacific caused by the effects of climate change. Currently, no studies have been conducted to determine the effects of climate change on malnutrition in the Pacific. However, it is anticipated that this study will help to fill this gap.

Food has been an essential part of Pacific Island culture and tradition for many generations. Visitors to the Pacific expect to see an abundance of food such as tropical fruit, vegetables and other supplies. However, this has been changing in recent times as the Pacific increasingly experiences an increase in malnutrition (both over and undernutrition) [Badcock, 1986]. Thaman, (1988) stated that nutrition of Pacific Islanders has shifted from fresh, nutritious local organic foods to dependence on imported canned and packaged foods. It is prevalent in urban areas but with many rural Pacific communities now accessible by road, and rural dwellers are not spared [Thaman, 1988]. Thaman, (1988) further added that there is evidence of energy, protein and vitamin deficiencies in rural areas. Some forms of malnutrition are common amongst infants in rural areas. In Papua New Guinea infant nutrition centres are full and also extreme cases of malnutrition have been reported in the Marshall and Northern Mariana. In rural Papua New Guinea, significant numbers of the children under five are suffering from underweight for children under the age of five, and Heywood, et al, (1992) found wasting for children under three, but with stunting rates decreasing rapidly after the first five years of life [Heywood and Morris-Hughes, 1992, Thaman, 1988]. In rural Papua New Guinea over half of the rural children under five (80%) were suffering from underweight [Thaman, 1988]. People in the highlands of Papua New Guinea and Vanuatu are at risk of protein deficiency, as they are isolated and do not have access to adequate protein compared to those in the urban areas. People in these areas consume sweet potatoes and cassava as their staple diets and have become accustomed to this diet [Walsh et al., 2012]. Anaemia used to be rare in the Pacific Islands and was only prevalent in the Cook Islands and Fiji, but has now spread to other island countries in the Pacific. Anaemia was high among pregnant women, infants and children. The increasing trend of malnutrition is due to the reduction in breastfeeding by mothers who replaced this with bottled baby formula, the unsafe weaning habits which include lack of knowledge of appropriate supplementary foods for babies, cultural practices and unsanitary conditions [Badcock, 1986, Hardy, 2003]. Thaman, (1988) also found that an increase in economic activity increases child growth rates, and changes in the diet improve health but can also lead to overnutrition [Walsh et al., 2012]. The studies that were conducted on malnutrition in the Pacific were from the 1990s. However, there is lack of research in this area in the 21st century. The possible reason is that as nutrition status has improved and other climate-sensitive diseases have become more critical the concern about malnutrition had decreased. This study will not only look at climate factors as one of the causes of malnutrition in Fiji but will explore other factors to determine the reason for the prevalence of malnutrition in Fiji during the study period.

## 1.4 Fiji

Fiji's climate is affected by the South Pacific trade wind belt where it is predominantly affected by the South-easterly trade winds. The country has a tropical maritime climate with two well defined seasons; November to April is the warm and wet season (summer) and May to October is the cooler dry season (winter). The seasonal cycle is affected by the South Pacific Convergence Zone (SPCZ). The southern edge of the SPCZ usually lies near Fiji and is more intense during the wet season. The geographical makeup of the main islands also affects the weather. Suva, which is on the windward side of the main island, is warmer and wetter than Nadi on the leeward side. There are no significant changes in the temperatures daily and seasonally due to the influence of the ocean surrounding the islands [Kumar et al., 2013, CSIRO et al., 2011, Mataki et al., 2006]. CSIRO, (2011) and Mataki, et al (2006) stated that the SPCZ and the south-easterly trade winds moving over the main islands of *Viti Levu* and *Vanua Levu* influence rainfall distribution in Fiji. The mountains in the centre of these islands modify the strength and the direction of the winds. Therefore, the differences in rainfall for the divisions is due to the considerable seasonal and inter-annual climatic variation. Thunderstorms are frequent in the summer and are responsible for sporadic high-intensity rainfalls. An active phase of the Madden Jullian Oscillation (MJO) closer to Fiji can cause a significant amount of rainfall for Fiji during the wet season [CSIRO et al., 2011, Mataki et al., 2006]. Mataki, et al (2006) added that temperature is uniform in low areas of Fiji and the daytime temperatures of the leeward side of the central island rise to 1 to 2°C more than those in the windward regions. Variation in seasonal and daily temperature variation is low due to the influence of the surrounding ocean. Historical records have shown that extreme temperatures were as low as 8°C and as high as 39.4°C [Mataki et al., 2006]. The period of 1970 to the present recorded a rapid increase in sea surface temperatures, with an increase of 0.07 °C per decade. A study conducted by Kumar et al (2013) on the temperature trend in Fiji showed that maximum and minimum temperatures are increasing from 0.08°C to 0.23°C per decade. These were observations from more than ten stations across the country within the last 78 years. There was a slight increase in the temperature trend for maximum temperature from 1989 to 2008 increasing to 0.18°C to 0.69°C per decade [Kumar et al., 2013]. The CSIRO (2011) report states that weather in Fiji is variable to the natural climate variabilities. Fiji's tropical cyclone season is from November to April, and there have been some cyclones that occurred in October and May during El Nino years [CSIRO et al., 2011]. In 2003 tropical cyclone Ami caused massive destruction in Fiji, especially in the northern division on the islands of *Vanua Levu*, *Taveuni* and the *Lau* group. The cyclone also brought floods in *Vanua Levu* and other parts of the country. In 2000 the floods in the Western division brought about significant destruction worth millions of dollars in damages. The 1998 drought in the western and the northern division caused significant damages to the sugar industry and Fiji's agriculture industry [Mataki et al., 2006]. CSIRO, (2011) added that the future climate projection for Fiji is an average projection representing the country and not specific to a town or city. Modelling done over the past forty years shows irregularities between the modelled and the observed temperature trends. The overall temperature projection for Fiji is an increase of 0.5 °C to 1 °C. ENSO will influence the inter-annual variability in the climate for Fiji. The total rainfall is expected to increase as the intensity of the SPCZ is predicted to increase [CSIRO et al., 2011]. Allen and Ingram (2002) added that the projected increase in rainfall is consistent with the global predictions based on scientific reasoning that the atmosphere retains more water vapour in a warmer climate [Allen and Ingram, 2002]. CSIRO (2011) and McBride, et al (2010) stated that as the prediction of rainfall increases, there is low confidence for drought projection for the Fiji Islands during the dry season. However, there is a slight increase in a mild drought from seven to eight times for every twenty years from 2030. Tropical cyclone projection for Fiji is

expected to decline during the 21st century. It supports studies conducted that suggest a global decline in the frequency of cyclones. Despite the projection of a reduced number of cyclones, some modelling simulation has shown that there will be an increase in the severity of cyclones [CSIRO et al., 2011, McBride et al., 2010]. Extreme weather events are a naturally occurring cycle in Fiji and the Pacific. However, the effects of climate change will intensify these extreme events.

Malnutrition has been a long-standing health concern for the Fijian health system for many years. One of the earliest studies conducted by Bahr, (1951) found three fatality cases of children under five from malignant malnutrition. The author described the Fijian people as a well-nourished race, but malnourished babies are a result of neglect and insufficient milk supply from the mother. In these early years, malignant malnutrition was not a recurrent issue in Fiji [Manson-Bahr, 1951]. Goodall, et al (1973) in their study found that the I Taukei diet was less expensive than the Fiji Indian diets, as the Fiji Indians used more expensive spices in their foods. For Many families income is insufficient, and there are more important things to pay for including rent, electricity and transport, leaving women and children with less food. I Taukei mothers stopped breastfeeding their babies at nine months and started with the supplementary foods of root crops and vegetables. The reasons given were the mother being pregnant, the child was sick, or she was separated from the child [Goodall et al., 1973]. It was still happening a years later during the National Nutrition Survey of 2004, showing I Taukei mothers were breastfeeding for nine months, and more I Taukei babies were malnourished after six months. The I Taukei babies were introduced to complementary feeding later at nine months as compared to the Fiji Indians at six months. The slow weaning process and the poor choices of supplementary food for I Taukei babies increases their risk of malnutrition from six months onwards [Schultz T. J et al., 2007]. The 2004 National Nutrition Survey also found the Fiji Indian babies to be more malnourished than the I Taukei babies due to their low birth weight, where for every I Taukei with low birth weight there were two Fiji Indian born with low birth weight. The maternal health, diet, the use of available prenatal care, the level of service delivery are possible contributing factors to the low birth weight. Atalifo, et al (2016) also found a similar trend where more I Taukei babies were healthy at birth and started showing signs of malnutrition after seven months, while more Fiji Indian babies were malnourished from birth to six months. They also found that I Taukei mothers breastfed their babies longer than Fiji Indian mothers and there were issues with the slow weaning process and the choices of complementary foods, and also a lack of protein in the babies diet [Schultz T. J et al., 2007, Atalifo et al., 2016]. These studies conducted on malnutrition in Fiji, show the prevalence of some of the risk factors of malnutrition amongst children under five. In the studies discussed there is no mention of climate change or the effects of climate change on malnutrition which may be due to the years the study was conducted in the 1950's and 70's where climate change impacts were minimal in the Pacific. The current study aims to fill in this gap. Malnutrition is a complex and multidimensional issue, and there is no single causal factor. This study will determine whether climate variables are one of the factors contributing to the prevalence of malnutrition in Fiji.



# Chapter 3

## Methods

The purpose of this study is to examine the association between climate change and malnutrition. The analysis of the association between indicators of climate change and indicators malnutrition was done using data from Fijian Ministry of Health and Medical Services and examination of documentation on climate-related variables. The researcher determined the prevalence of malnutrition. The researcher also analysed climate variables, indicators of malnutrition, and agricultural production data from Fiji. Using the time series analysis, the researcher determined their trend using moving averages. The researcher examined existing literature on factors that can affect variation in the prevalence of malnutrition prevalence. The works of literature were grouped into the following themes: extreme weather events, socioeconomic factors, water and sanitation, and other factors associated with malnutrition. The following sections provide the details of the procedures.

### 1 Overview of the methods

The Fiji Meteorological Services is the only government department in Fiji that collects climate data for Fiji. A standardised form is available on their website (<http://www.met.gov.fj>). The researcher used the standardised form and was able to collect the following climate-related variables for the period between 1st January 2009 and 31st December 2016:

- monthly averaged maximum temperature
- monthly averaged minimum temperature
- monthly averaged total rainfall
- monthly averaged humidity

The climate variables for the period 2006 to 2008 was excluded from the analysis because there were insufficient corresponding malnutrition classification dataset available for comparison. The reason for the omission of the malnutrition data from 2006 to 2008 from the analysis is explained in the malnutrition data subsection. The primary purpose of this study is investigating the relationship between climate change variables (temperature, rainfall and humidity) and the prevalence of malnutrition in Fiji. The temperature was chosen as it is an indicator of global warming which is causing climate change. Relative humidity is a measure of water vapour

in the atmosphere in relation to the amount of water vapour the air can hold before rainfall [Barreca, 2012]. The total rainfall and relative humidity were also chosen as they are linked to temperature, as temperature increases there is a higher chance of evaporation and extreme precipitation. These climate parameters are measures on a daily basis in the nine strategically located weather stations in Fiji and available when requested. These climate parameters were used by McIver, et al (2012) when using a time series Poisson regression model on monthly cases of diarrhoea and monthly rainfall in Suva, Fiji [Barreca, 2012]. Grace, et al (2012) used the temperature and rainfall parameters when looking at child malnutrition and climate in Sub Saharan Africa [Grace et al., 2012].

The following variables were considered an indicator of outcomes:

- monthly counts of underweight children
- monthly counts of children with growth faltering
- monthly counts of children with severe malnutrition
- monthly counts of children with anaemia

For each month, new counts of children who were reported to have these features were tallied.

## 2 Steps of data collection and linkage

### 2.1 Climate Data

Climate data were extracted from the Fiji Meteorological Service (“FMS”) for the years January 2006 to December 2016. The FMS database had the average monthly maximum temperature, average monthly minimum temperature, the average monthly humidity and the average monthly total rainfall. The FMS collects daily climate data from the nine weather station sites of Ba, Labasa, Lakeba, Laucala, Nadi, Nausori, Ono-i-lau, Savusavu and Rotuma (Figure 3.1).

The weather monitoring stations are located in the four divisions of Fiji and provide a representative reading of the climate variables for the country. The FMS has given the monthly readings as the average of the monthly readings. The researcher grouped the monthly recordings of maximum, minimum temperature, total rainfall and relative humidity for each of the stations on a spreadsheet. The columns had the climate variables and the months and the rows had the weather stations. The average of the monthly climate readings from the nine weather stations was the reading for Fiji. The researcher created spreadsheets where the average readings for the climate variables were in the columns and the months on the rows. The readings showed the average maximum, minimum temperatures, average rainfall and average humidity for Fiji from January 2006 to December 2016 (see figure 3.2)

### 2.2 Data on Malnutrition

The researcher obtained approval from the Fijian Ministry of Health and Medical Services ethics committee (‘Committee’) to access the data set on malnutrition (“malnutrition dataset”). The researcher excluded data for the years between 2006 and 2008 as the malnutrition data for these years had different classifications compared with malnutrition data for the years 2009 through 2016 and hence could not be compared. For the years 2009 - 2016, the Ministry of Health



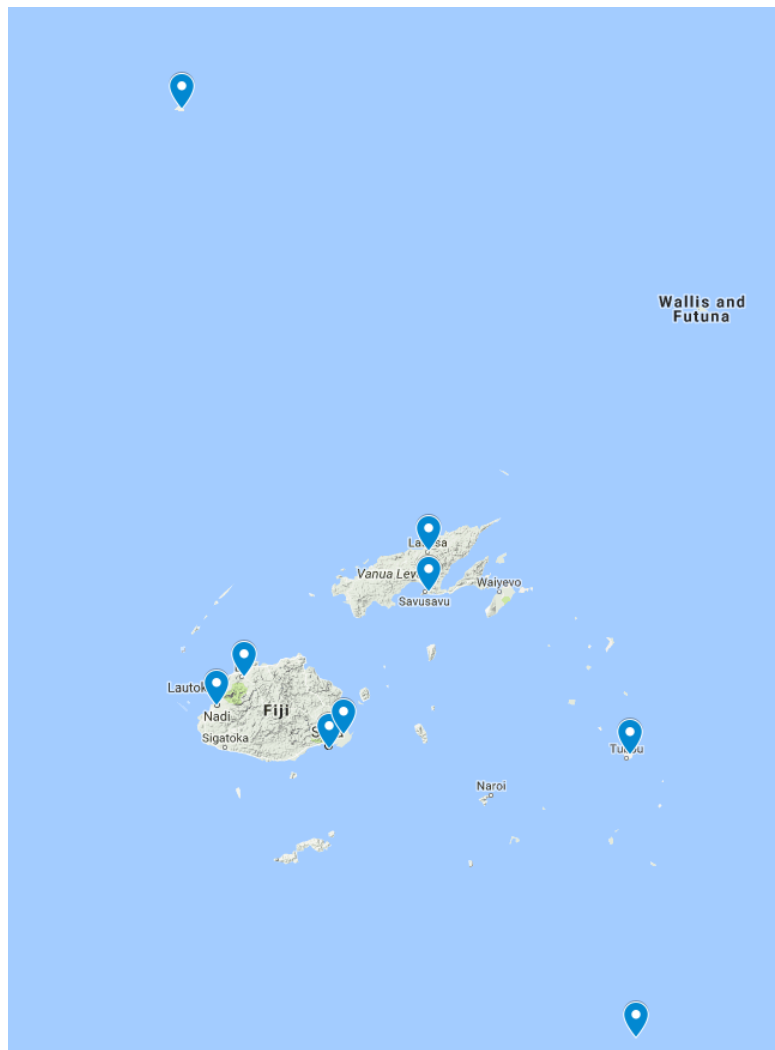


Figure 3.1: The figure shows the map of the weather monitoring sites around Fiji. The furthest station in the north of Fiji is in Rotuma, and the one further south is in Ono i Lau.

classified malnutrition as mildly underweight, moderately underweight and severe underweight based on the consolidated monthly return format.

### Definition of classifications of malnutrition in Fiji

The Fijian Ministry of Health has been using the National Center for Health Statistics (“NCHS”) definitions until 2008, where malnutrition was classified as mild, moderate and severe underweight as low weight. The (“WHO”) standards have been used from 2009 onwards where underweight is determined by weight for the age where children whose weight are more than -2 standard deviations of the WHO child growth standards median. The next classification of malnutrition in Fiji is growth faltering which is an interruption in the growth of a child after comparison with

1	DATE	max_temp	min_temp	total_rainfal	min_relative_humidity
2	2006-01-31	30.8	23.4	410.4	79.8
3	2006-02-28	31.1	23.9	301.7	81.3
4	2006-03-31	31.9	24.1	155.2	80.5
5	2006-04-30	30.8	23.2	180	79.1
6	2006-05-31	29.7	22.1	202	78.4
7	2006-06-30	28.3	21.2	140.4	80.55
8	2006-07-31	26.9	19.3	70.7	76.3
9	2006-08-31	27.7	18.2	96.8	77.9
10	2006-09-30	28.6	21.2	169.2	77.4
11	2006-10-31	28.1	22.1	177.2	78.5
12	2006-11-30	30	22.7	150.9	74.5
13	2006-12-31	30.2	23.5	251.1	76.7
14	2007-01-31	31.7	23.9	104.9	76.8
15	2007-02-28	31	24.3	393.6	84
16	2007-03-31	30.5	24	517.7	85.6
17	2007-04-30	30.5	23.4	277.3	84.4
18	2007-05-31	29.6	21.8	183.5	80.5
19	2007-06-30	29.5	22	57	79.4
20	2007-07-31	28.9	22	112.9	79.9
21	2007-08-31	29	21.6	91.6	77.1
22	2007-09-30	29.7	22.6	225.2	81.2
23	2007-10-31	30.1	22.8	252.6	80
24	2007-11-30	30.2	20.6	343.9	78.9
25	2007-12-31	30.6	23.1	281	79.3
26	2008-01-31	30.3	23.2	593.3	83.1
27	2008-02-29	30.8	23.6	300.6	83.1
28	2008-03-31	30.9	23	218.1	81.8
29	2008-04-30	30.7	22.8	251.9	80.2
30	2008-05-31	28.7	21.5	281.3	79.8
31	2008-06-30	28.7	21.3	270.9	83.5
32	2008-07-31	28.1	20.2	112.7	76.2
33	2008-08-31	29.1	21	72.1	78.6
34	2008-09-30	29.3	21.2	117.3	75.7
35	2008-10-31	30.1	22	123.8	75.2

◀ ▶
final climate data
+

Figure 3.2: The figure shows the grouped recordings of the maximum, minimum temperature, total rainfall and relative humidity for each of the stations on a spreadsheet .

children of the same age and gender in early childhood. Severe malnutrition includes children suffering from stunting and wasting. The (“SAM”) and (“MAM”) were introduced in 2016 after cyclone Winston affected Fiji. However, this classifications will not be included in the study as it will come under severe malnutrition. The last classification of malnutrition is anaemia where the nurses and the dietitians physically examine the babies at the clinics for signs and symptoms (pale skin, rapid heartbeat, brittle nails, sore or swollen tongue), and this is confirmed through haemoglobin testing. The malnutrition dataset used for this research consisted of malnutrition cases collected in months starting 31/1/2009 till 31/12/2016. Each of the datasets was separately stored for each year on different spreadsheet files (see Appendix for the spreadsheets).

### Ethics

The ethics approval form contained the abstract, and the title of the research, the proposal details such as the institution, supervisors details, the research was national research and the data collection was a secondary data collection. The risk assessment were all answered with no as there were no research subjects, and the level of risk involved in the research was no more than minimal risk. The Ethics Approval form can be found in the Appendix section of the thesis.

The Committee approved the request on the 10th of August 2017 with two conditions:

- the chair of the ethics committee must be notified of any changes or variation to the project and any incidence or adverse events regarding study subjects
- The project is subject to monitoring by the committee and the findings of the study to be presented back to the participating institutions

Following approval to obtain data, the ethics committee secretary informed the Health Information Unit to release the ‘malnutrition dataset’ after the endorsement of the permanent secretary of health. The data set was distributed in the form of a spreadsheet that was sent to the researcher by electronic mail from the Ministry of Health Information Unit.

The researcher preprocessed the dataset as they were stored directly from the main dataset onto the spreadsheet.

The researcher excluded data on “severe anaemia” as no classification of severe anaemia was available for the years 2013 to 2016. To maintain consistency, the researcher included only those data that were available for all years between 2009 and 2016. If some data were not available for a few years, then the researcher excluded that data from further analysis. It was used to standardise the dataset and was applied to the dataset from 2009 to 2012. The 2013 to 2016 dataset already had the sheets separated into the different months with the header having the division, the subdivision, the medical area, the ethnicity, and the classification of malnutrition (severe malnutrition, anaemia, low weight, growth faltering).

### Malnutrition data

The Ministry of Health and Medical Services in Fiji (“MOHMS”) provided malnutrition data for children from birth to five years. The researcher abstracted raw counts of malnutrition cases from these databases and estimated the prevalence of malnutrition using the following formula:

$$Pr = \frac{Nm}{Ns} \times 100 \quad (3.1)$$

where Pr is the prevalence, and Nm is the number of children with malnutrition, Ns is the number of children seen at the Clinics

MOHMS used two types of reporting systems to record malnutrition in their database, (1) the consolidated monthly return information system (“CMRIS”) and (2) the Public Health Information System (“PHIS”). The CMRIS was used to estimate the levels of malnutrition for the years between 2006 and 2008. This dataset contains information only on the underweight children – a measurement of low weight for age. The ‘low weight for age’ is defined as when the child’s weight is less than what is expected of his or her age, it is the reflection of the body mass relative to age. Weight, unlike height, fluctuates and it reflects the current, acute and chronic stages of malnutrition. Therefore it is useful in monitoring growth and degree of malnutrition

in children. It was divided into three categories ‘mild, moderate and severe underweight’ as per the classification under the National Center for Health Statistics. Severe underweight refers to weight for age less than the 60th percentile, moderate underweight refers to weight for age is the 60th and the 74th percentiles, and mild is from the 75th to the 89th percentiles on weight for age measurements basis. The categories were separately reported under each ethnic groups. The “I-Taukei” group is the indigenous people of Fiji, and the “Fiji Indians” are Fijians of Indian decedents and “Others” which included all other races in Fiji. As this system is not used anymore, the researcher did not use the dataset any further.

The introduction of the PHIS in 2009 changed the classifications of malnutrition cases. The new classification is severe malnutrition, severe anaemia, anaemia, low weight and growth faltering. Moreover, from 2013 onwards, severe anaemia was excluded from the classification. The malnutrition classifications included the ethnicity of the children. However, the gender and age groups of the children were excluded from the database from 2006 to 2016. The Ministry of Health Information Unit did not provide information on age and gender of the children; hence it was not possible to include this information in the thesis or data sets.

A spreadsheet was used to record the prevalence of underweight, severe monthly malnutrition, anaemia and growth faltering from 2009 to 2016 inclusive of both 2009 and 2016, hence eight years of data. For each of underweight, malnutrition and growth faltering, the researcher had 96 rows of data, and each row is represented as a month. The 2009 to 2016 malnutrition dataset was used as it contained the same type of malnutrition classifications (underweight, growth faltering, severe malnutrition and anaemia). The CMRIS definitions of malnutrition for 2006 to 2008 were omitted from the finalised dataset because it had different classifications from the rest of the dataset and if was used for the analysis it would only for the three years and then a separate classification for the next seven years. The malnutrition prevalence and trend is more clear over a more extended period, and it is better to use the seven years available data for malnutrition than the three years. Therefore 84 rows of data that were used were the malnutrition dataset from January 2009 to December 2016, which is 84 months. It contained the same classifications throughout the 84 month period.

The malnutrition counts include underweight, growth faltering, severe malnutrition and anaemia. The researcher created a separate dataset because the raw data for growth faltering, severe malnutrition and anaemia was only available from 2009 to 2016. The dataset for 2006 to 2008 has only raw counts of mild, moderate and severe underweight as their classifications.

## 2.3 Other Variables

The researcher used the following variables to adjust for the relationship between climate-related variables and malnutrition.

**Food availability** is determined by local and imported food in the country. Rural and urban Fijians consume staple diets that include root crops, fruits and vegetables from farms. Therefore some of the food consumed is sourced locally. The effect of climate change through the manifestation of extreme weather events increases the risk of damaging crops and limiting access to fresh food to the Fijian population which can lead to increase in the prevalence of malnutrition.

The other variable is the **market price** for the for agricultural produce. The price of the agricultural produce depends on the availability of crops, and the production of crops depend on the climate and other factors such as land, fertiliser and farming equipment. The market price for agricultural products tends to increase when there is an occurrence of extreme weather

events (droughts, floods and cyclones) because there is limited supply and the demand is high. It can have an effect on malnutrition prevalence as nutritious food will only be affordable to those that can purchase it, leaving a considerable number of people in the community at risk of malnutrition.

The **socioeconomic factors** include household income and the availability of water and sanitation. These are social variables that increase the risk of malnutrition in the general population. Studies have indicated that socioeconomic status is linked to malnutrition in children [Jelliffe, 1966]. In urban Africa wasting in children are influenced by the mother's occupation, when mothers have a real occupation they can provide for the family [Delpeuch et al., 2000]. Children living in very low food security households or low and middle income were highly likely to develop iron deficiency anaemia, stunting, wasting and underweight, than those living in high food safety or high-income households, as they cannot afford to purchase or grow their foods [Vellakkal et al., 2015]. Due to the warming climate precipitation levels will not be uniformly distributed worldwide, some areas will receive more rainfall and other less, therefore causing droughts and floods in different areas [Bernstein et al., 2007]. Water and sanitation are essential fundamentals in public health and the lack of these influences outbreaks of waterborne, water-based, water-related, excreta-related and toxin-related illness which has secondary effects associated with malnutrition [Montgomery and Elimelech, 2007]. Infectious diseases related to water and sanitation is linked to 60% of child mortality [UNESCO, 2003]. Lack of water prevents hygienic practices, children not washing their hands after using toilets and before eating, making them vulnerable to infectious diseases [Montgomery and Elimelech, 2007]. Water shortage prevents communities from growing vegetables for proper nutrition making them susceptible to nutrition deficiencies [Gerald et al., 2006]. Even though the scenarios are happening elsewhere, it can very likely occur in Fiji. Therefore it is considered as it can also affect the prevalence of malnutrition in Fiji. A formal letter of request was written to the Permanent Secretary for Agriculture to allow the researcher to extract data relating to food security. The permanent secretary approved the request and referred the issue to the Economic and Planning and Statistics Division unit where they have the agricultural statistics. The Ministry of Agriculture supplied the crop production data and market price for agricultural commodities. The researcher also collected socioeconomic dataset from Fiji Bureau of Statistics and the water and sanitation dataset from the Environmental Health Unit in the Ministry of Health and Medical Services. Prior approval was obtained from their respective departmental heads before the data was released.

The Ministry of Agriculture, Economic Planning and Statistics Division provided the data on food crop production. The Ministry of Agriculture has crop production data in their database. The food availability data is taken from crop production in quarters from 2009 to 2016 as this was the data available at the Ministry of Agriculture headquarters. The monthly data for the crop production is available at the divisional officers, but due to the limited time to conduct the research, the researcher only the available data at the head office.

The socioeconomic dataset and the water and sanitation datasets had missing data and hence omitted from the present analyses. The Fiji Bureau of Statistics provided the socioeconomic dataset that contained the number of wage and salary employees. The data for employment was available for the years 2006, 2007, 2009, 2010, 2011 and 2014. To get the real effect of the socioeconomic covariate on the outcome of the study, it needs to be consistent throughout the seven years or the 84 data points. The socioeconomic dataset was also not used in the study due to the inconsistencies in the dataset. The Ministry of Health Environmental Health Unit released the water and sanitation dataset. The sanitation data classification were flush, pour flush, dry latrines and no latrines and stored in percentages under rural, urban and national

categories for 2007, 2009 and 2014. The same database has the drinking water dataset for Fiji. The drinking water is categorised as tap water, groundwater, rainwater and surface water under urban, rural and national for the years 2007, 2009 and 2014. However, it was omitted from the study because of the same reason the socioeconomic dataset was removed. The removal of the water and sanitation covariate from the study was due to the inconsistency in the data and the missing data for the study period.

### 3 Data Processing and Analysis

The researcher linked the three datasets as follows. A spreadsheet was created and a dataset named "climate variables" that contained the climate variables from January 2006 to December 2009. The dataset had on the header the date which contained the month and the year, the average maximum temperature for the month, the average minimum temperature, the total rainfall and the relative humidity. A series of datasets were created for each malnutrition classification. The header of each of the dataset contained the years, the ethnicity and the prevalence. It was replicated for underweight, growth faltering, severe malnutrition and anaemia. The dataset was done so that barplot for the prevalence of malnutrition for each ethnicity was determined for the study period. Another series of datasets were created for each of the climate variables and also for each of the malnutrition classifications. There was only one header which contained the climate variable or the malnutrition classification (this was the counts of malnutrition for all the ethnics groups together and not the prevalence). This was done so that it would be converted to a time series dataset and also where the smooth moving average trend can be calculated and plotted. The final dataset contained the date, the maximum temperature, the minimum temperature, the total rainfall, the relative humidity, underweight, growth faltering, severe malnutrition and anaemia on a single spreadsheet.

Step one of analysis is descriptive analysis, hence the construction of a table for climate variables (average maximum and minimum temperature, average rainfall and average humidity). A table was also constructed for crop production from 2009 to 2016 with the headers showing the years, first quarter, second, third, fourth and the total crop production.

The next step was using the R Studio software to construct barplots for malnutrition. Separate bar plot graphs were done for underweight, growth faltering, severe malnutrition and anaemia. The barplots had different colours indicating the different ethnic groups that were malnourished for that year. The codes for the barplots are attached in the appendix.

#### 3.1 Time Series Analysis of Data

The researcher conducted time series analysis to describe the trend of the climate variables using the dataset created where only the readings of each of the climate variables were on the spreadsheet. A time series analysis is a sequence of data points recorded at different time points. It is commonly used when there are 50 or more data points in the series, and when considering seasonality, there should be at least 4 or 5 cycles in the data. Time series data have a natural ordering, such as the days, months, quarters, years and so forth which makes it distinct from cross-sectional studies. Time series data can be either stationary or non-stationary. A stationary time series are those whose properties such as mean, variance and autocorrelation are all constant over time and a non-stationary time series is a series where its properties change over time. There are few goals when using time series analysis one is it can be used to determine underlying trends,

it can be used to understand and model the data, and it can be used for short-term forecasting trends from previous patterns. In this study, it was used to provide a descriptive analysis where it identified patterns in correlated data which are the trend and seasonal variation of the climate variables and malnutrition prevalence.

The researcher examined each time series for climate and malnutrition variable to determine if there were any patterns in the series. If there is a pattern existing the series is divided into two parts to show how they have differed and it will be discussed. The R codes for this is attached in the appendix. The seasonal plot and seasonal variation are used to determine the seasonality patterns. Next, the researcher looked at how the malnutrition population behaved for each month of the year for all the years (2009-2016), and the same was done for the maximum and total rainfall using the seasonal deviation plot. This is done to determine if there is a pattern where some months have higher malnutrition cases than the others or high temperature or rainfall than the others and it can determine if there is seasonality in the series. The R codes for the seasonal plot and the seasonal deviation plot is attached in the appendix section.

### 3.2 Examination of the data for missing data and outliers

The time series for climate variables and malnutrition were individually plotted and examined for any outliers, volatility, or irregularities. During the examination process of the dataset, it was found that there were outliers in the total rainfall, growth faltering and severe malnutrition. The outliers were removed using the `tsclean()` function as part of the R package that identifies and replaces outliers using series smoothing and decomposition. The R codes for preprocessing the particular climate and malnutrition dataset are found in the appendix. When the outliers were removed, the datasets were still volatile. To determine a trend or pattern for the graph where it smooths out the noisy fluctuations, a concept in time series known as moving average be used. The moving average was used to smooth out the noise in the time series data.

### 3.3 Constructing Moving Averages

In order to determine the trend and seasonality of the variables the researcher used a smoothing method called moving average (MA). The moving average of order  $m$  is calculated by taking the average of series  $Y$ ,  $k$  periods around each point :

$$MA = \frac{1}{m} \sum_j^k = -k^Y t + j \quad (3.2)$$

where the  $m = 2k + 1$ . The moving average is used to remove the random fluctuations in the time series to show a clear existence of other components. A moving average smoothing was used as it averages the values in that period and those close to it. The researcher used the moving average window of three to determine the trend and seasonality. To determine the seasonality effect on the time series the smoothing average was for three months. The longer the moving average period it creates a stronger smoothing effect and a shorter smoothed series. The moving average of six months was done for the climate and the malnutrition variables. The six month period was selected to allow for seasonal variation, thus assuming six months to a season for tropical countries like Fiji. The R codes for the moving average is attached in the appendix. Even after smoothing the data there is still some volatility in the time series, and it needs to be addressed, the data is then decomposed.

### 3.4 Decomposition of the Data

Decomposition is the process of extracting the components of a time series. The components of the time series are the seasonal component which refers to the seasonal fluctuations in the data to the seasonal cycle. The trend component which is the overall pattern of the series, the cycle component refers to the variations in the patterns without any seasonal effect and the residual or the error term where seasonal or trend components can not cause part of the series. The time series used an additive model for this study. An additive model is used as in climate variables the amplitude of the seasonal effects is the same each year. The model is also used for the malnutrition variables as the study want to know whether malnutrition is affected by seasonal changes. An additive model of

$$Y_t = S_t + T_t + E_t \quad (3.3)$$

where the  $Y_t$  is the data at period  $t$ ,  $S_t$  is the seasonal component,  $T_t$  is the trend-cycle component and  $E_t$  is the error component of period  $t$  was used for the study. When the additive model is used, it shows the patterns of the climate and the malnutrition variables during the study period. There is another method known as the multiplicative model which uses logs. However, it is used for the dataset that has a huge variation in their dataset. In this study, the decomposition was done for each climate and malnutrition classifications. The decomposition extracted the raw data, seasonal, the trend and the error or white noise. The researcher then extracted the raw data and the trend to be plotted on the graph. It was plotted together with the smoothing to see how the time series analysis using the smoothing and the decomposition eliminates the outliers, fluctuations and white noise to determine the trend of the series. The R Codes for the decomposition is attached in the appendix section. The researcher also de-seasonalised the time series for the malnutrition variables to remove the seasonal effects of the time series and see how the malnutrition variables pattern.

### 3.5 Stationarity of the Data

For a series to be stationary, the mean, variance and the autocovariance should be time invariant. The augmented Dickey-Fuller (ADF) test is a formal statistical test to determine for stationarity, where the null hypothesis assumes that the series is non-stationary. For this to happen the contribution the contribution of the lagged value to the change in  $Y$  is non-significant, and there is a presence of a trend component, the series is, and the null hypothesis is not rejected. The climate and the malnutrition data were each tested for stationarity using the augmented Dickey-Fuller (ADF) method statistical test for stationarity. The R codes for the stationary test is attached in the appendix section.

### 3.6 Testing the Autocorrelation functions

The autocorrelation plots or autocorrelation functions (ACF) are a useful visual aid in determining the stationarity of the series. If the series correlates with the lags, then there are some trend or seasonal components, and therefore the properties are not constant over time. The ACF plots show a correlation between series and lags. The ACF plots not only suggest the differencing order it, but it can also determine the order of the M A (q) model. Partial autocorrelation plots (PACF) display a correlation between a variable and its lags that is not explained by previous lags, and it is useful in determining the order of the A R (p) model. The stationary time series



will have the ACF fall quickly, but the non-stationary will drop gradually. The R software plots 95% significance boundaries as blue dotted lines.

### 3.7 Literature Review

Pieces of literature were searched using Google Scholar, Medline, Embase search engines and the University of Canterbury library database. The researcher used four themes in the literature review, namely climate change, nutrition, Pacific islands and Fiji. The researcher used the common search words such as climate change, climate change and health, health effects of climate change when searching for literature in the first theme. The next theme, nutrition, the search words used was malnutrition, undernutrition, climate change and malnutrition, increased temperature and malnutrition, rainfall and malnutrition. The next theme on Pacific islands the search words used was the climate in the Pacific, climate change in the Pacific, health effects of climate change in the Pacific and malnutrition in the Pacific. The last theme is named Fiji, the common search words used is the climate in Fiji, climate change in Fiji and malnutrition in Fiji.

### 3.8 Qualitative Analysis

The qualitative analysis is similar in a way to the literature review where there were themes identified and works of literature and also government reports, laws and policies and grouped. The researcher identified the literature using search engines such as the Google, Google Scholar, the University of Canterbury Library and Science Direct. The themes identified were extreme weather events and malnutrition, policies and malnutrition, water sanitation and malnutrition, socioeconomic factors of malnutrition, effects of climate change on food security and malnutrition and other factors associated with malnutrition. In the theme, extreme weather and malnutrition search words used included floods and malnutrition, droughts and malnutrition and cyclones and malnutrition. In the policies and malnutrition, the researcher looked for policies on malnutrition in Fiji through the Google search engine. The theme of water and sanitation, the search words were used was the effect of water and sanitation on malnutrition. The theme socioeconomic factors on malnutrition, the search words used were mothers occupation and malnutrition, poverty and malnutrition and income levels and malnutrition. The food security and climate change theme the search words used were food availability and malnutrition and food accessibility and malnutrition. In the last theme of other factors associated with malnutrition, the researcher used the words accessibility to health facility and malnutrition, mothers education and malnutrition, multiple births and malnutrition, and other factors of malnutrition.

## 4 Ethical Consideration

Ethical approval was obtained from the Ministry of Health Research Committee (NHRC) on the 10th of August 2017. The process was needed to access medical data regarding the prevalence of malnutrition from the Ministry of Health Health Information Unit database. The malnutrition data stored at the Health Information Unit is in aggregated form. Therefore there is no violation of privacy as the names of children suffering from this medical condition are not available in the database. The University of Canterbury's ethics approval was obtained on the 13th September 2017 on the basis that ethics was approved from Fiji. Approval was also sought from the Fiji Meteorological Office for the climate data from 2006 to 2016 and also from the Ministry of

Agriculture for the food security data from their database. Approval was also sought from the Fiji Bureau of statistics for socio-economic data.

# Chapter 4

## Results

### 1 Summary of the results from climate & nutrition variables

The results from the analysis of the trends in climate and nutrition variables are summarised below.

Variables	Months	Median	Mean	SD	25th & 75th percentile
Monthly Average Maximum Temp	96	29.8	29.72	1.34	[28.6] ; [30.8]
Monthly Average Minimum Temp	96	22.45	22.24	1.39	[21.07] ; [23.4]
Monthly Average Total Rainfall	96	173.45	194.32	118.73	[98.53] ; [264.07]
Monthly Average Relative Humidity	96	78.6	78.76	2.62	[77.08] ; [80.72]

Table 4.1: *The distribution of the climate variables from January 2009 to December 2016. The table shows the months, median, mean standard deviation figures in single columns and while the (25th and 75th) percentiles are together in a single column separated by brackets .*

Table 4.1 shows the climate variables collected for each month from January 2009 to December 2016. The average maximum and minimum temperatures for the period January 2009 to December 2016 shows that the median was higher than the mean which means that it was a distribution of temperature readings have skewed left or a negative skew. The total rainfall shows that the median was less than the mean which was a right skew of the distribution of rainfall. It also means that there was variation in rainfall patterns, there are some months where there are incredibly high rainfalls and some months with less rainfall, and there are differences between the 25th and the 75th percentiles. The mean and the median of the relative humidity was very close which means that the humidity was randomly distributed within the 96 month period.

#### 1.1 Time Series analysis

Time series analysis was used to examine the trend of average maximum temperature, average minimum temperature, average total rainfall and average minimum relative humidity from

January 2009 to December 2016 and the malnutrition (underweight, growth faltering, severe malnutrition and anaemia) variables using moving average and decomposition of the series.

### Climate Variables

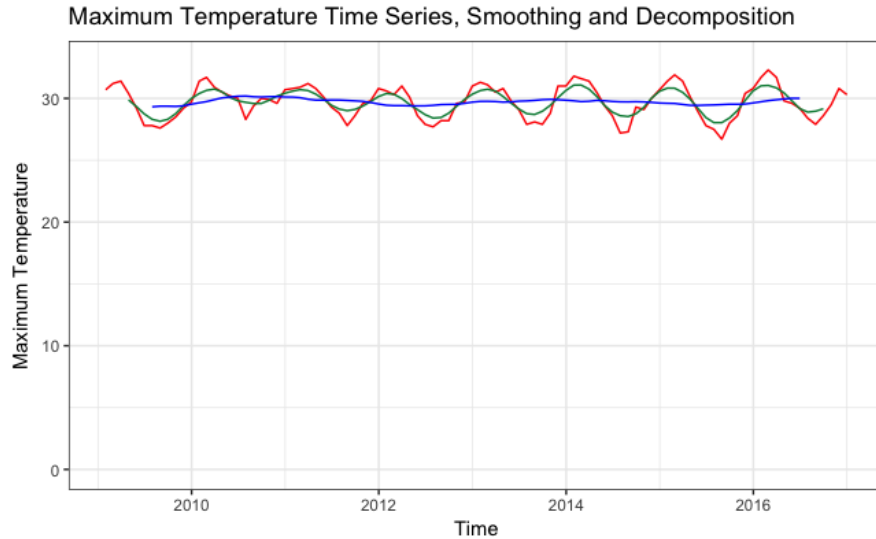


Figure 4.1: *The figure shows three lines on the graph showing the monthly average maximum temperature time series, its smoothing using the simple moving average and decomposition.*

Figure 4.1 shows the  $x$ -axis has ticks which represent the years of data recording. The graph shows three lines which represent the time series, the smoothing and the trend from the decomposition of the series. The green line represents the average monthly maximum temperature after using a simple moving average of order 6, where smoothing was added to the time series. The time series data was then decomposed, and the trend was extracted and plotted on the plot which was represented by the blue line on the graph. The  $y$ -axis shows the readings for the period average maximum temperature. The red lines represent the fluctuations of the raw monthly average maximum temperature. The monthly average maximum temperature raw data time series shows that it follows a seasonal cycle and the smoothing also follows a similar pattern but smooths out the splines and the white noise. The smoothing shows the monthly average maximum temperature showing a similar but smooth cycle. After the decomposition of the time series, the trend showed there was not much variation in the monthly average maximum temperature from 2009 to 2016.

Figure 4.2 shows on the  $x$ -axis the months and the  $y$ -axis the maximum temperature. The graph demonstrates the seasonal fluctuations of maximum temperatures for each month from 2009 to 2016. The maximum temperatures are high between November to April and low between May to September, the hottest month was February and the coolest month was August. The seasonality patterns were similar for all the years from 2009 to 2016.

Figure 4.3 shows the  $x$ -axis the study period and the  $y$ -axis the maximum temperature. The graph shows the trend of monthly average maximum temperature after decomposition and

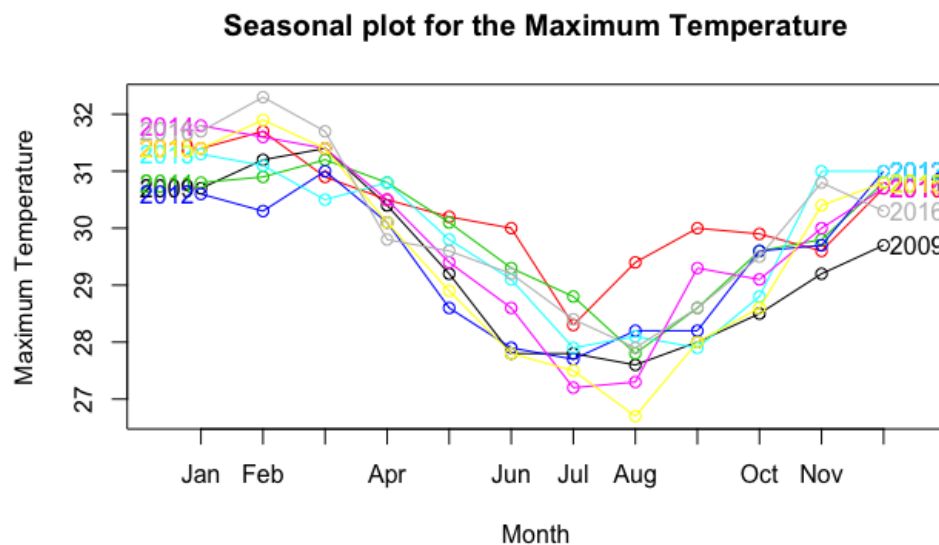


Figure 4.2: The figure shows the monthly seasonal fluctuations for maximum temperature indicated by a different colour for each year between 2009 and 2016. The seasonality pattern shows the maximum temperature was high at the beginning at the end of the year, and low in the middle of the year .

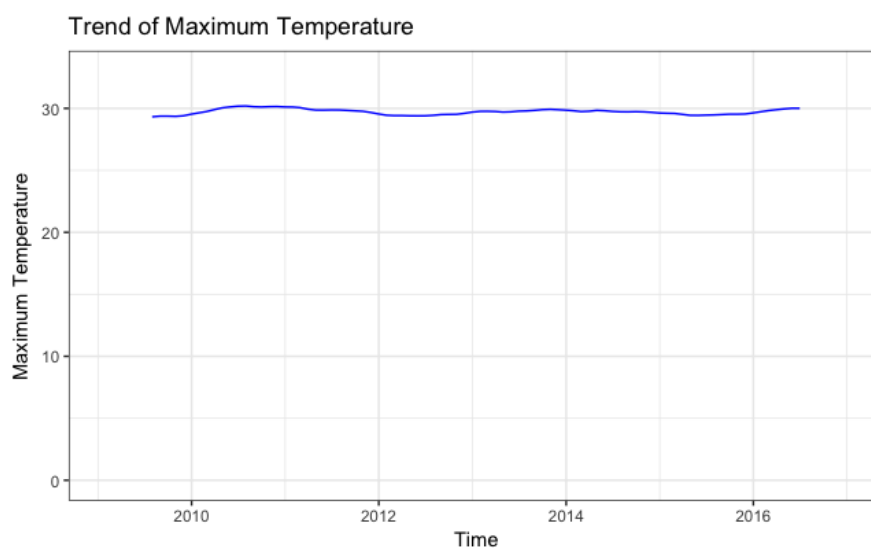


Figure 4.3: The figure shows the trend of the monthly average maximum temperature after smoothing and decomposition of the time series.

smoothing. The graph shows that there was minimal variation in the average maximum temperature for Fiji from 2009 to 2016.

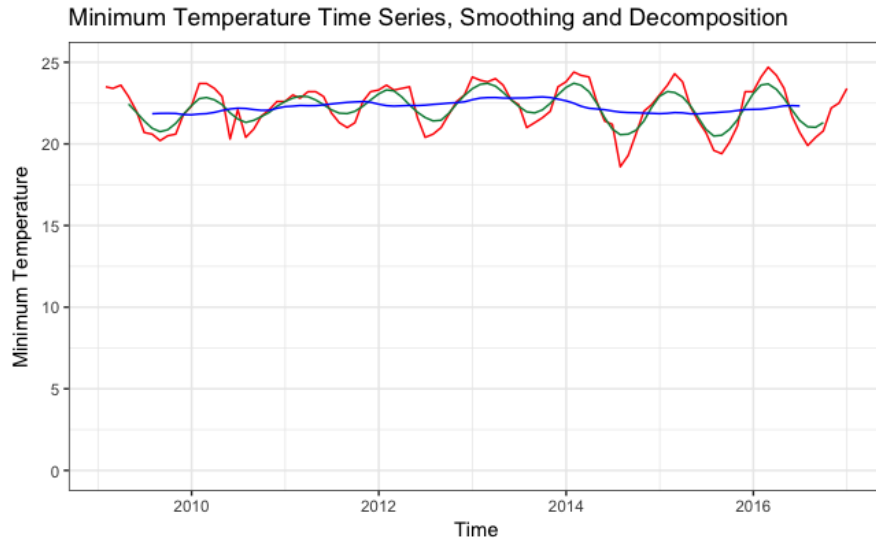


Figure 4.4: The figure shows three lines on the graph showing the monthly average minimum temperature, its smoothing using the simple moving average and its decomposition

Figure 4.4 shows that on the  $x$  - axis the ticks represents the period of data recording. The graph shows three lines which represent the time series, the smoothing and the trend from the decomposition of the series. The red line represents the time series for monthly average minimum temperature. The green line represents the average monthly minimum temperature after using a simple moving average of order 6, where smoothing was added to the time series. The time series data was then decomposed, and the trend was extracted and plotted on the plot which was represented by the blue line on the graph. The  $y$  -axis shows the readings for the period average maximum temperature. The time series for minimum temperature (red line) shows that it was following a seasonal cycle. After smoothing was done as shown by the green line, it shows a similar pattern but minimising the splines. The trend does not show much of a variation.

Figure 4.5 has on the  $x$  - axis the months and the  $y$  - axis the minimum temperature. The graph shows the monthly seasonal fluctuations for minimum temperature between 2009 and 2016. The hottest month was February and the coolest month was July for the minimum temperature, and the pattern was similar for all the years in the study.

Figure 4.6 shows the  $x$  - axis the period of the study and the  $y$ - axis the minimum temperature. The graph shows the trend of the minimum temperatures from 2009 to 2016. The trend of average minimum temperature was achieved after smoothing and decomposing the time series. The monthly average minimum temperature trend for the study period did not have much of a variation. It was almost showing a similar trend as the average maximum monthly temperature, but with a slight decrease from 2014 to 2016.

Figure 4.7 shows that on the  $x$  -axis the ticks indicate the years of data recording. The  $x$  -axis also shows the bar plots representing the months of the data collection. The graph shows three lines which represent the time series, the smoothing and the trend from the decomposition of the series. The green line represents the average monthly total rainfall after using a simple moving average of order 6, where smoothing was added to the time series. After the smoothing, the time series data was then decomposed, and the trend was extracted and plotted on the plot,

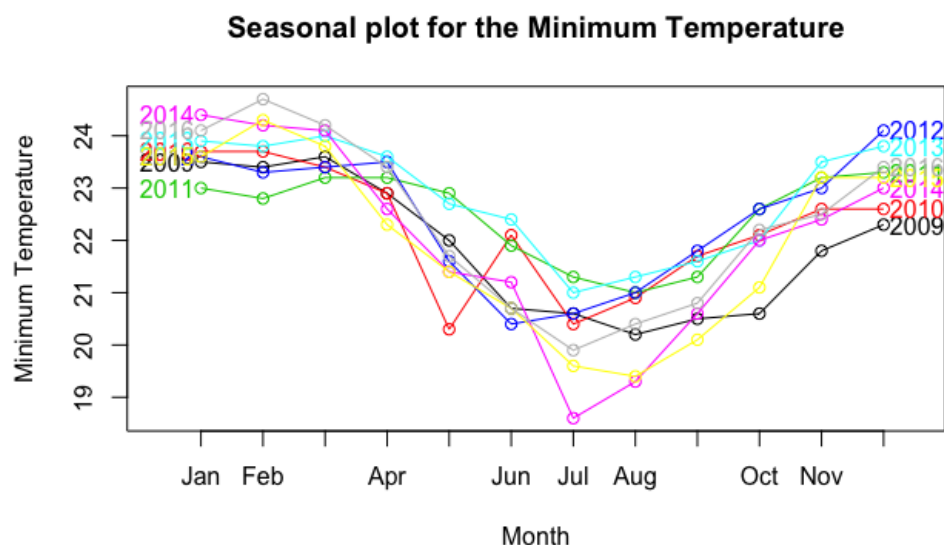


Figure 4.5: The figure shows the monthly seasonal fluctuations of the minimum temperature. The colours represent the years when the seasonality was plotted, and temperatures were high at the beginning and the end of the year and low in the middle of the year.

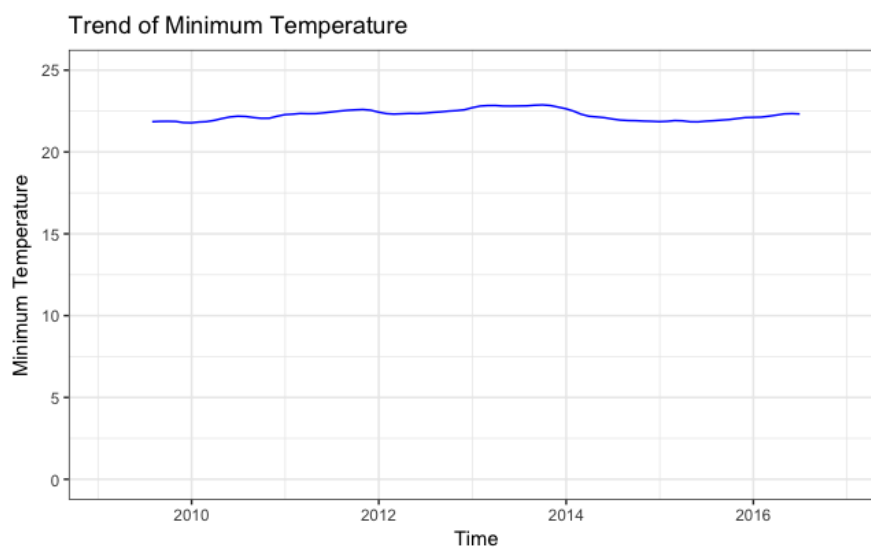


Figure 4.6: The figure shows the trend of the monthly average minimum temperature from 2009 to 2016.

represented by the blue line on the graph. The  $y$ -axis shows the readings for the period average maximum temperature. There was fluctuation in the rainfall patterns from 2009 to 2016 with some months having extremely high rainfalls and some months having low levels. There were

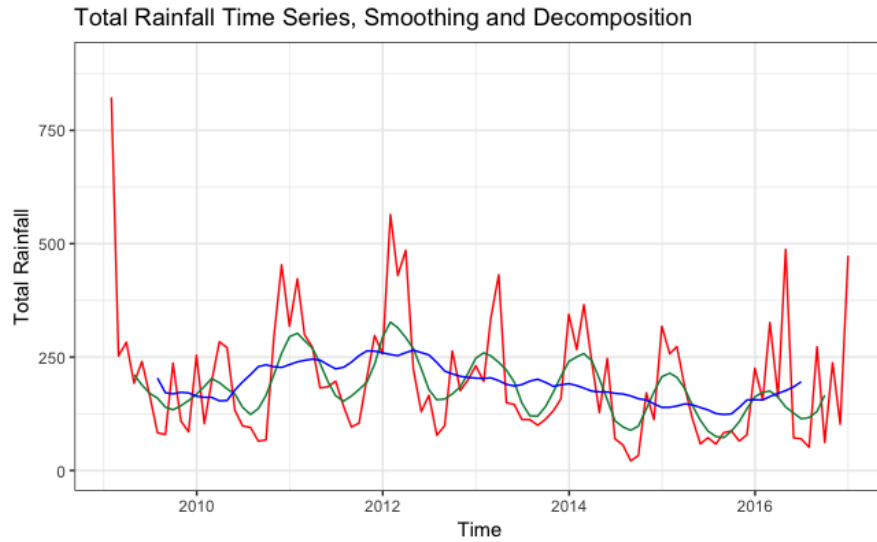


Figure 4.7: The figure shows the average monthly total rainfall time series, the smoothing of the series using the simple moving average of six and trend after the decomposition of the smoothed series.

two high rainfall readings recorded one month apart in 2012, while others were isolated months with high rainfalls.

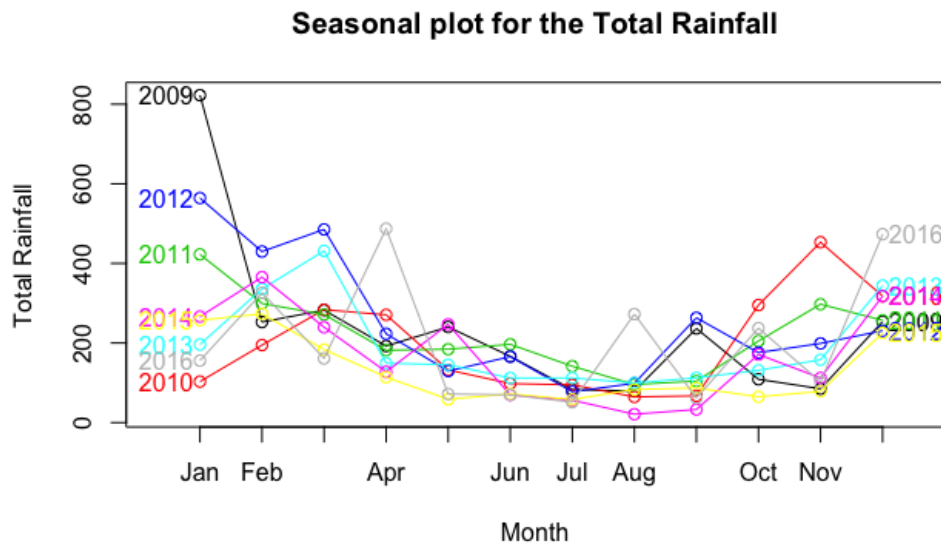


Figure 4.8: The figure shows the seasonal variation of total rainfall in months. The different colors represents the years, this was between 2009 and inclusive of 2016.



Figure 4.8 shows on the  $x$ - axis the months and on the  $y$ - axis the total rainfall. The graph shows the monthly total rainfall between 2009 and 2016. A different colour represented each of those years on the graph. The high rainfall seasons was seen between November to April and the dry season was between May to September.

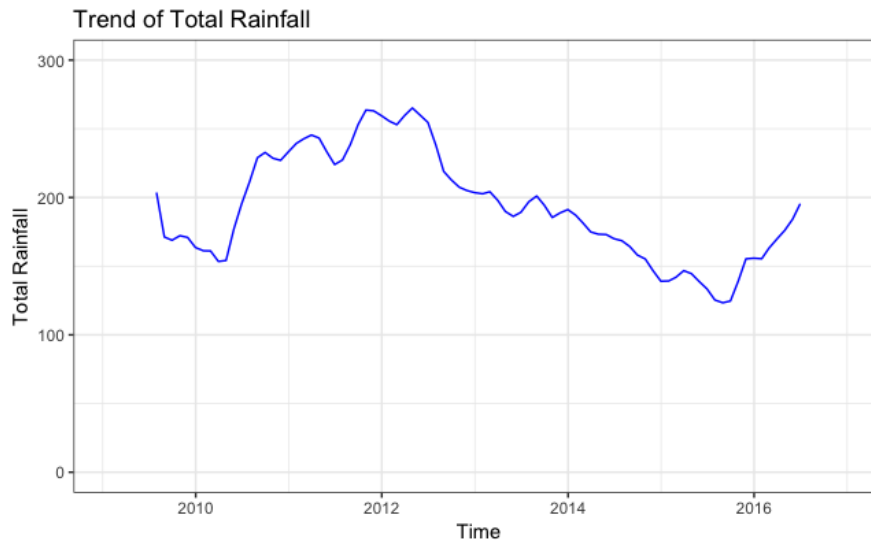


Figure 4.9: The figure shows the trend of the average total rainfall after decomposing the smoothed series from 2009 to 2016.

Figure 4.9 shows the trend of total rainfall from 2009 to 2016. The  $y$  axis shows the trend of average total rainfall and the trend was examined after decomposing and smoothing the time series. The  $x$  axis shows the years of data recording. The trend shows that that the total rainfall were increasing from 2010, a slight decrease in mid-2011 and high increases at the end of 2011 and beginning of 2012. The rainfall was on a gradual decrease from mid-2012 towards its lowest point at the end of 2015. At the end of 2015, the rainfall increases steeply towards 2016.

Figure 4.10 shows that there ticks on the  $x$ -axis which represents the years the data was recorded. The  $x$ - axis also had three line running through it which represents each of the functions used by time series. The red line represents the time series of humidity, and the green line represents the smoothing of the time series using the simple moving average of six. The blue line represents the trend which was examined after decomposing the smoothed time series. The  $y$ -axis shows the reading for the monthly average humidity. There was not much variation in the monthly average relative humidity from 2009 to 2016. The time series shows much fluctuation in humidity, and the smoothing shows that the humidity was following a cycle.

Figure 4.11 shows on the  $x$  - axis the months and on the  $y$  - axis the total relative humidity. The graph shows that seasonality of humidity was increasing from the beginning of the year from January to June and then decreases from July to September and increases from October to December. Humidity was less in the middle of the year and more at the beginning and the end of the year.

Figure 4.12 shows the trend of humidity from 2006 to 2016 after decomposing the smoothing using the simple moving average of the time series. The  $y$  axis shows the trend of average total

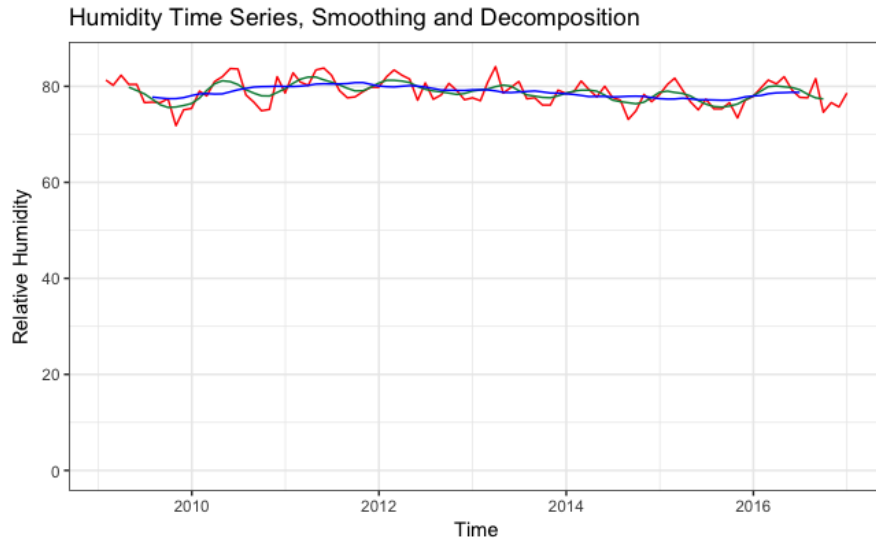


Figure 4.10: The figure shows the humidity time series, the smoothing of the series using the simple moving average window of six and the decomposition of the smoothed series.

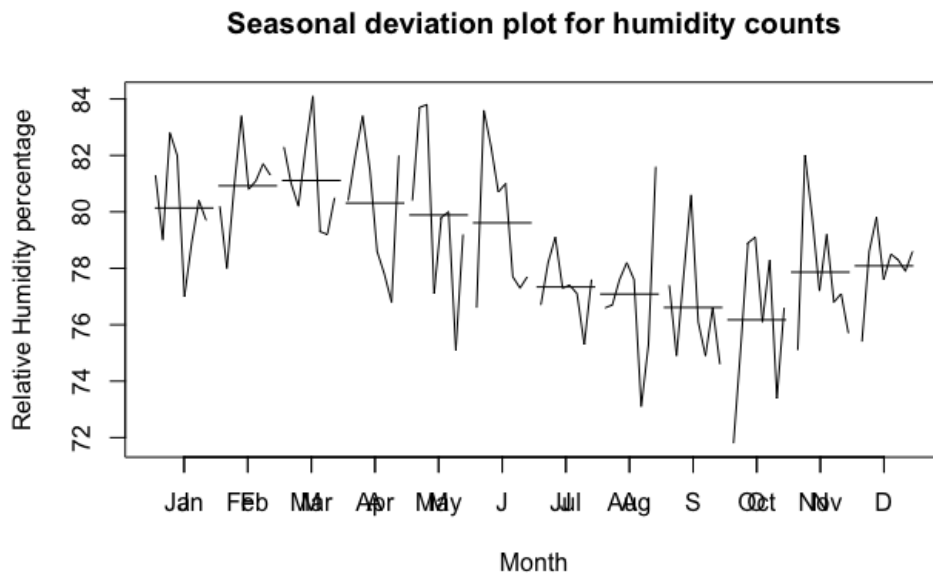


Figure 4.11: The figure shows the seasonality of the monthly total relative humidity between 2009 and 2016. The years are represented by different colors and it shows no seasonality pattern.

humidity, and the  $x$  axis shows the years of data recordings. There was not much variation in the average total humidity trend, but a slight decrease in the humidity levels from 2013 to 2016.

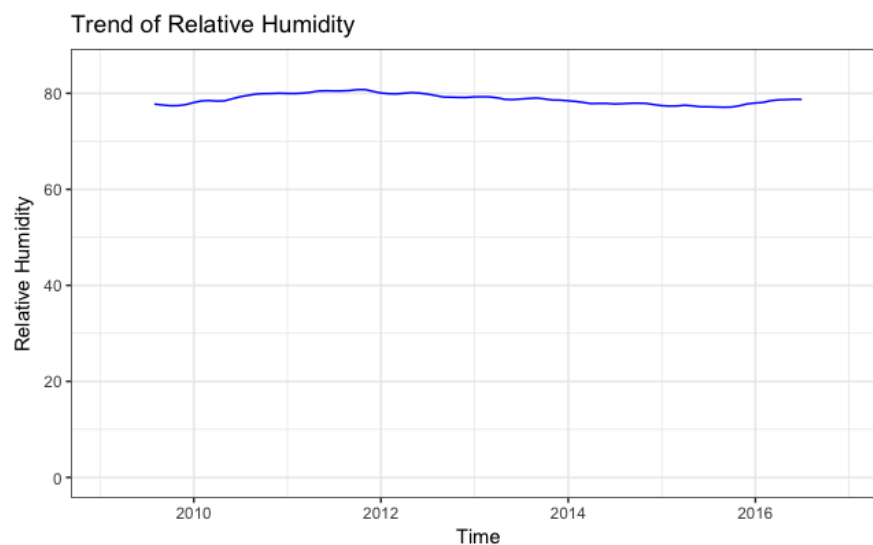


Figure 4.12: The figure shows the trend of average total humidity after decomposition of the smoothed series for 2009 to 2016.

## Malnutrition

Time series analysis was conducted for each individual classifications of malnutrition

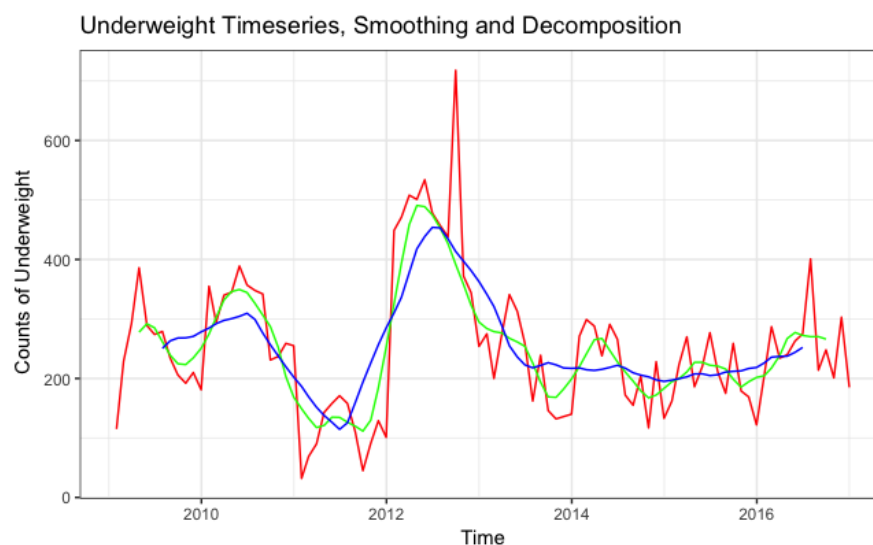


Figure 4.13: The graph shows the time series for underweight, the smoothing using the simple moving average of order six and the trend after the decomposition of the series

Figure 4.13 shows on the y-axis the counts of underweight and on the x-axis the time the data was recorded. The graph shows three lines which represent the time series, the smoothing and the

trend from the decomposition of the series. The red line represents the time series of underweight, and the green line represents the smoothing of the time series using the simple moving average of six. The blue line represents the trend which was examined after decomposing the smoothed time series. The time series showed that there was much jaggedness in the series, there were two periods of high underweight in 2012 and a low period in 2011. The smoothing using the simple moving average showed the underweight decreasing from 2010 into 2011 and increased into 2012, it did not follow the second period of increased in 2012 which indicates that it could be an outlier. The trend which was examined after the decomposition of the smoothed series was plotted was discussed in the figure below.

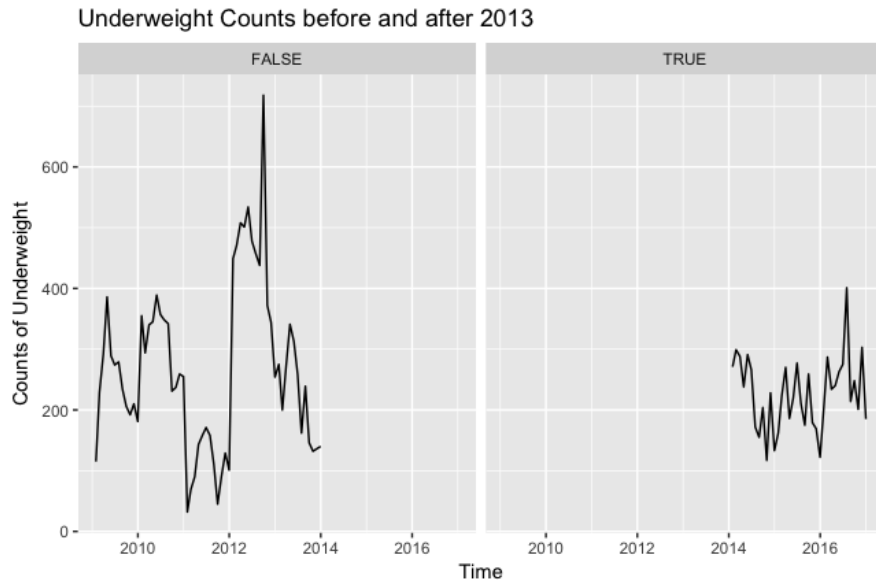


Figure 4.14: The figure shows two graphs with showing the underweight time series. The graph on the left shows the underweight before 2013 and the one on the right shows the underweight after 2013. .

Figure 4.14 shows on the  $x$ -axis the counts of underweight and the  $y$ -axis the time in years. Two graphs are showing the underweight time series before 2013 on the left and after 2013 on the right. The counts of underweight were fluctuating between 2009 and 2010, and it increased in the middle of 2011 and dropped again at the end of the year. At the beginning of 2012, the counts of underweight increased sharply and then dropped at the middle of the year before a big increase during the third quarter of the year, then a decrease into 2013 and then it fluctuates towards the end of 2013. For the second graph, the counts of underweight drops from the beginning of 2014 and then fluctuates from the middle of 2014 to 2016. At the beginning of 2016, the counts of underweight increased to the middle of the year, before falling again towards the end of the year.

Figure 4.15 has on the  $x$ -axis the months and on the  $y$ -axis the counts of underweight population. The graph shows there was a spike in September, but despite the spike, over an average, the count of underweight babies increased from January to July and then dropped. In this graph, the counts of underweight babies were less at the beginning and the end of the year, with high counts in the middle of the year.

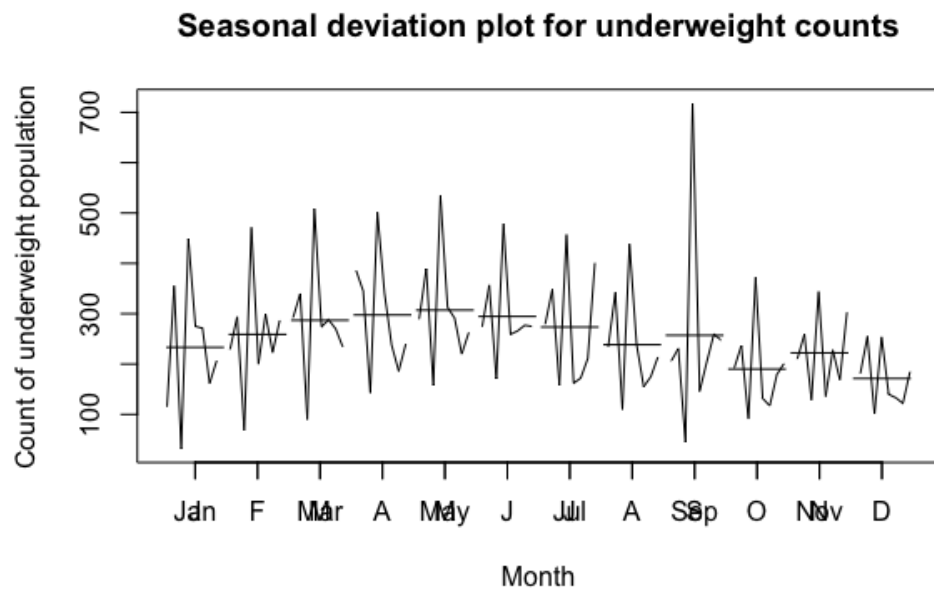


Figure 4.15: The figure shows the seasonal deviation plot for underweight counts. The counts of underweight was generally low at the beginning and at the end of the year, despite a spike in September.

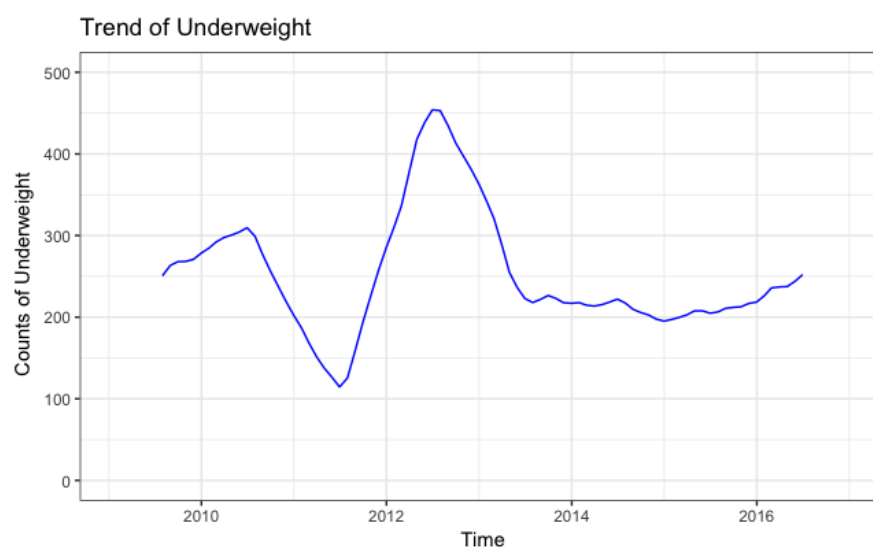


Figure 4.16: The figure shows the underweight trend from 2009 to 2016. The trend was decreases rapidly in mid-2010 towards mid-2011 and then a sharp increase to its peak in mid-2012, then rapidly decreases again into mid-2013 before becoming stagnant.

Figure 4.16 shows the underweight trend from 2009 to 2016. The  $y$  axis shows the trend of underweight children after smoothing and decomposing the time series. The  $x$  axis shows the years of data collection. The underweight trend started to decrease from 2010 into to 2011, and then in mid-2011, it started to increase sharply to its peak in the middle of 2012. The trend then decreased from mid-2012 into mid-2013 before it became stagnant through to 2016.

The countries using the National Center for Health Statistics (“NCHS”) child growth standards have found that weight for age falters between 3 to 12 months and recovers from 19 months. The weight for height growth faltered after birth and was significant in the first 24 months [Rieger and Trommlerová, 2014]. The diagnosis pathways for growth faltering will be changes in weight gain, through physical examination and observation in the behavioural changes [Government of Western Australia, 2014]. Fiji’s health system was using the weight for age as an indicator of child growth. The medical personnel at the health facility identifies growth faltering children through anthropometric measurements and also referring to the standards in the maternal child health (“MCH”) card, and the card has the standards derived from the NCHS. A sample of the MCH card was attached in the appendix.

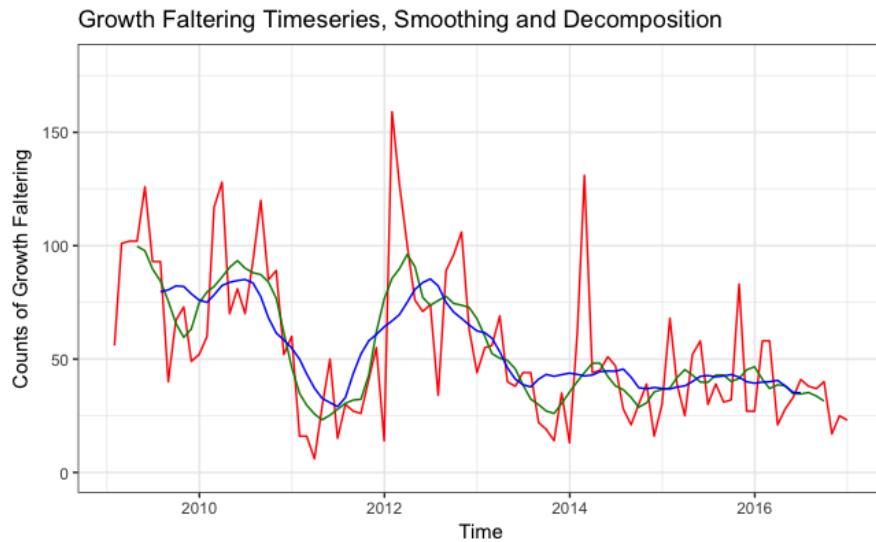


Figure 4.17: *The figure shows time series of Growth Faltering from January 2009 to December 2016, the smoothing of the time series with the simple moving average order 6 and the trend from the decomposition of the smoothed series.*

Figure 4.17 shows the  $y$  - axis represents the counts of growth faltering and the  $x$ - axis represents the period the data was recorded. The graph shows three lines which represent the time series, the smoothing and the trend from the decomposition of the series. The red line represents the time series of growth faltering, the green line shows the smoothing of the series using the simple moving average of six, and the blue line indicates the trend after the time series data was smoothed and decomposed. The growth faltering time series shows high counts in 2009, 2010, 2012 and 2014, after smoothing the counts were decreasing from 2010 into 2011 and increased into 2012 and gradually decreased into mid-2013 and the blue line indicated the trend.

Figure 4.18 shows the  $x$ - axis time in the form of years and the  $y$  - axis the counts of growth faltering. The growth faltering series has more spikes on the left than on the right. The counts

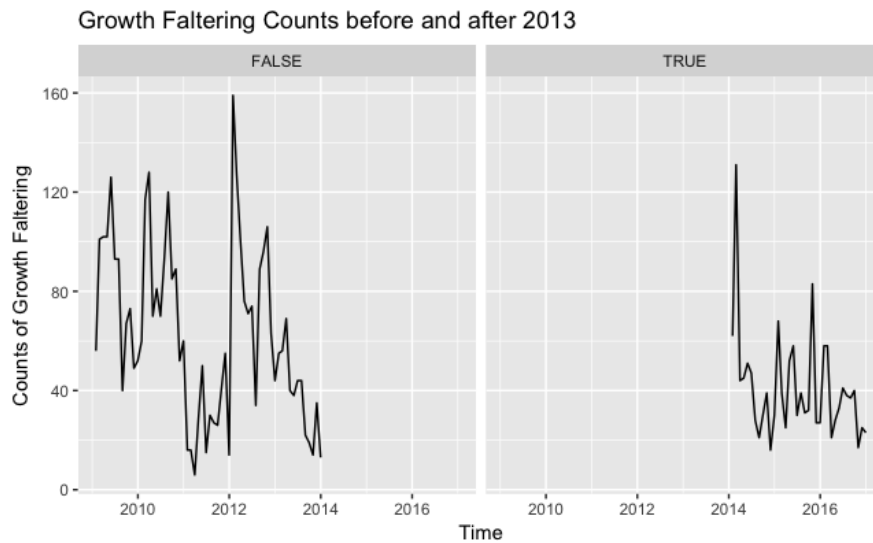


Figure 4.18: The figure shows two graphs of counts of growth faltering, the one on the left represents the year before 2013 and the one on the right the year after 2013.

of growth faltering were fluctuating between 2009 and 2010, and at the beginning of 2011, the counts decreased to its lowest point in the series. The counts were fluctuating in 2011 and decreased at the end of 2011. At the beginning of 2012, the counts increased to its highest point and then decreased in the middle of the year before increasing again, then decreased at the end of the year. The counts of growth faltering then decreased from the middle of 2013 towards the end of the year. In the second graph, the counts of growth faltering increased at the beginning of the year and then it fluctuated through to the end of 2016.

Figure 4.19 has on the  $x$ -axis the months and on the  $y$ -axis the counts of growth faltering population. The graph shows counts of growth faltering population increases at the beginning of the year and decreases and was stagnant in the middle of the year and decreases at the end of the year. There were high counts of growth faltering between January to March and in October.

Figure 4.20 shows the  $y$  axis shows the counts of growth faltering children after smoothing and decomposing the time series. The  $x$  axis shows the years the data was collected. The growth faltering trend was high in 2010 and started to decrease in the into the middle of 2011, and then it sharply increased into mid-2012 and then gradually decreased into mid-2013.

Low height for age (stunning) and low weight for length (wasting) are methods of assessing severe malnutrition. These are extreme malnutrition cases which require hospital admission or home treatment with diet management plan. Wasting or thinness was the measurement of the child's weight against his/her height [Victoria, 1992]. Severe hunger or severe illness was often the cause of wasting in children. The prevalence of wasting was usually high when children are two years old [Victoria, 1992]. Stunting was a low weight for age and was a sign that the child has failed to reach linear growth potential due to poor health and nutrition [De Onis et al., 1993]. There are standards followed by different countries to examine the ideal weight of a child to his or her height. Many countries are using 1976 WHO/National Center for Health Statistics (NCHS) and some 2006 WHO standards [Martorell and Young, 2012].

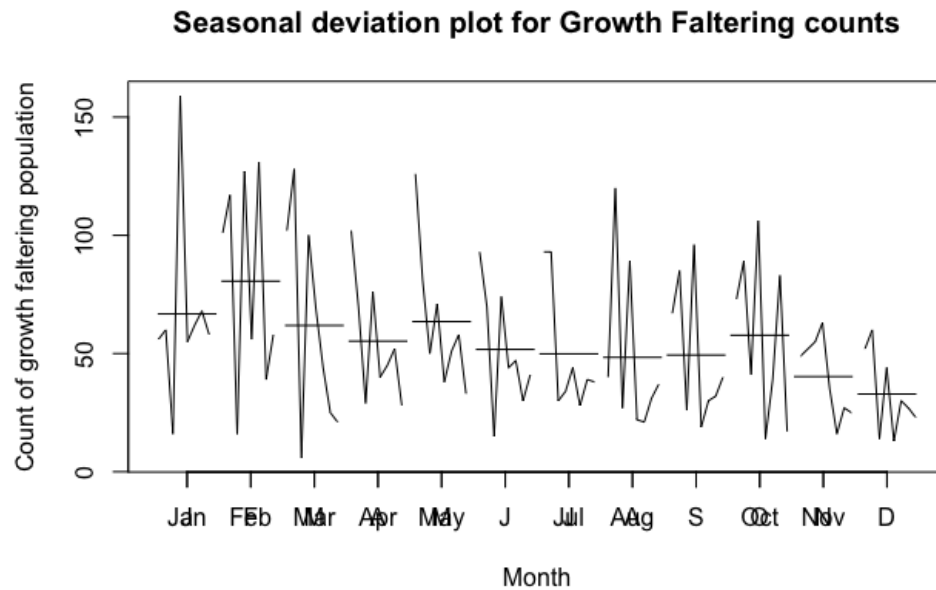


Figure 4.19: The figure shows the seasonal deviation plot for growth faltering counts. The counts of growth faltering were high at the beginning of the year and then decreases and remains constant throughout the year with a slight increase in October .

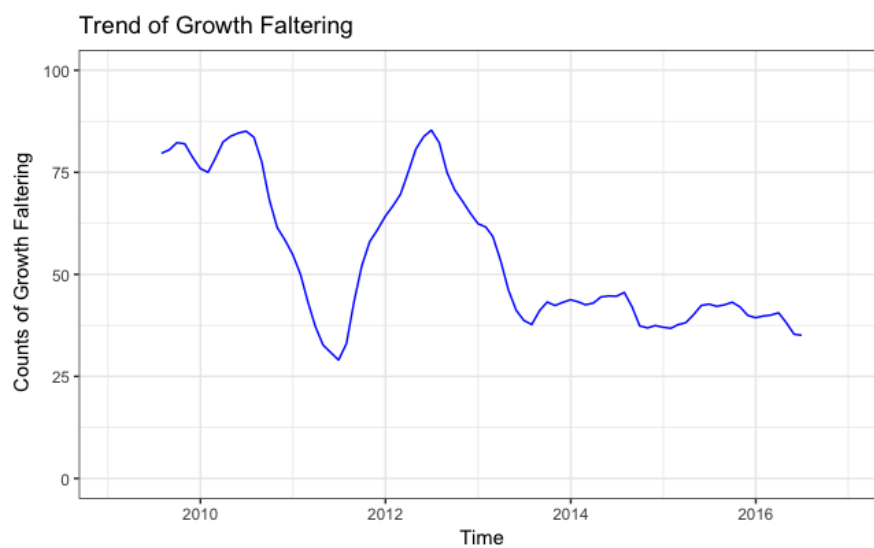


Figure 4.20: The figure shows the trend growth faltering from 2009 to 2016. The trend shows a drop in growth faltering in 2011 and 2014, an increase in 2010 and 2012.

Figure 4.21 shows that on the y-axis was the counts of severe malnutrition and on the x-axis was the period the data was collected. The graph shows three lines which represent the time series,



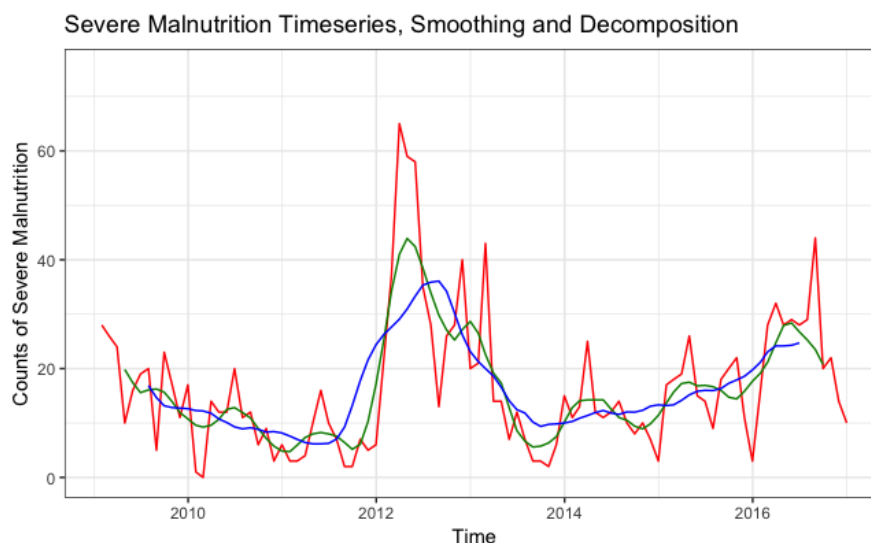


Figure 4.21: The figure shows the time series of severe malnutrition from January 2009 to December 2016, the smoothing and the decomposition trend of the series.

the smoothing and the trend from the decomposition of the series. The red line shows the time series of underweight, the green line shows the smoothing of the series using the simple moving average of six, and the blue line shows the trend after the decomposition of the smoothing series. The time series indicates that there were two increase in severe malnutrition in 2012 and increase in 2013 and 2016. The smoothing line showed that severe malnutrition was decreasing from 2010 and increased in late 2011 into 2012 and decreased into 2013 and then fluctuates after that and the blue line shows the trend of the series.

Figure 4.22 shows the  $x$  - axis shows the time represented by years and the  $y$ - axis shows the counts of severe malnutrition. The figure shows two graphs, the one on the left represents the counts of severe malnutrition before 2013, and the graph on the right represents the counts of severe malnutrition after 2013. The two graphs are different, the one before 2013 there was an increase in severe malnutrition counts were decreasing from 2009 and an increase in 2010, then there was an increase in the middle of 2011, a decrease later in the year and a steep increase in 2012. At its highest point in 2012, the counts decreased in the middle of 2012 but increased near the end of the year. At the beginning of 2013, the counts of malnutrition started to decrease, and it continued to the end of 2014. The second graph displayed fluctuations in the counts of severe malnutrition between 2014 and 2015, and the counts increased at the beginning of 2016 and continued to the middle of the year and then decreased at the end of the year.

Figure 4.23 has on the  $x$ - axis the months and the  $y$ - axis the counts of severe malnutrition. The graph shows the counts of severe malnutrition population increasing at the beginning of the year and decreases in the middle of the year and then increases at the end of the year. High counts of severe malnutrition were noted in March, April and May and in November at the end of the year.

Figure 4.24 shows the  $y$  axis was the trend of severe malnutrition and the  $x$  axis shows the years when the data recorded. The trend was achieved after the decomposition of the smoothed time series. The trend shows the severe malnutrition was decreased into 2011 and then increased

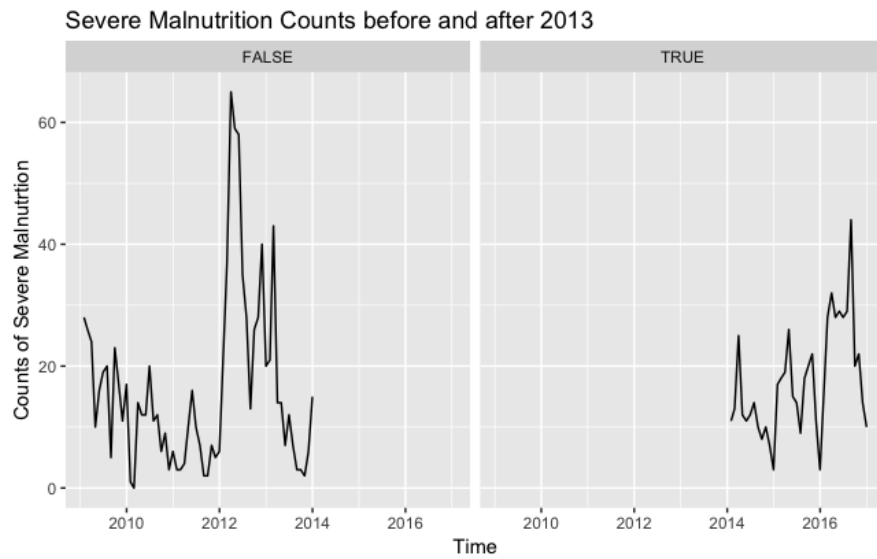


Figure 4.22: The figure shows two graphs of counts of severe malnutrition, the one of the left represents the series from 2009 to 2013 and the one on the right was the series after 2016.

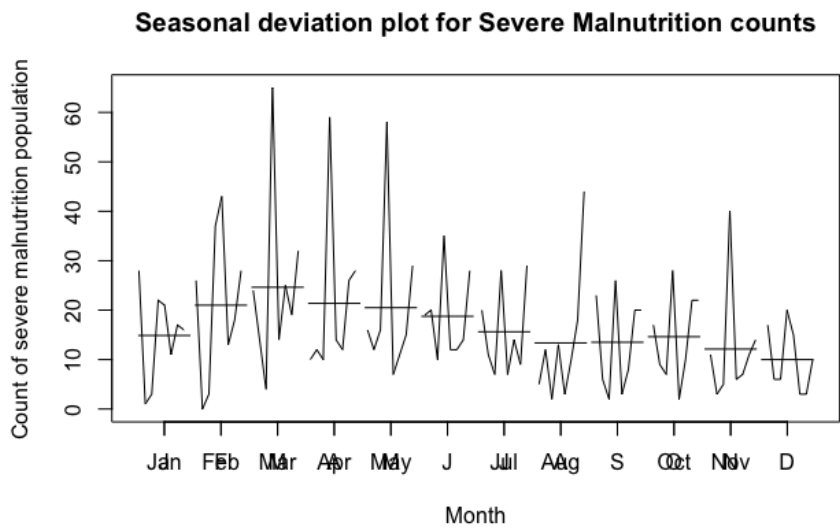


Figure 4.23: The figure shows the seasonal deviation plot for severe malnutrition population. The graph shows an increase in severe malnutrition from January to June and decreases to the end of the year.

from mid-2011 into mid-2012 and then decreased from mid-2012 into mid-2013 and gradually increased into 2016.

Anaemia was a micro-nutrient deficiency which was the lack of particular nutrients in the body.

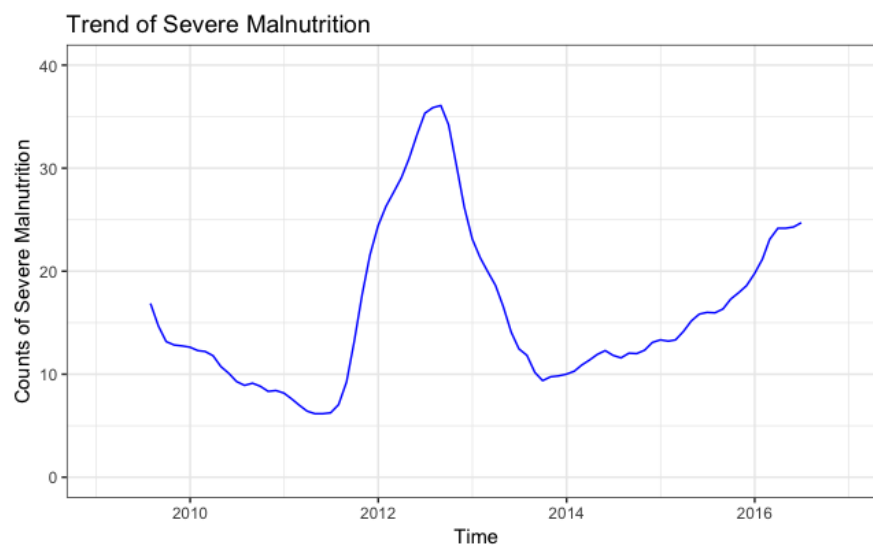


Figure 4.24: The figure shows the trend severe malnutrition from 2009 to 2016. The trend was decreasing from 2010 into mid-2011 and increased into 2012. The trend decreased from mid-2012 into mid-2013 and then in gradually increased into 2016.

Iron and vitamin deficiency anaemia was common in children. In Fiji, diagnosis of anaemia was through physical examination of the child at the clinic, if the child was showing signs and symptoms, they undergo a haemoglobin test for confirmation.

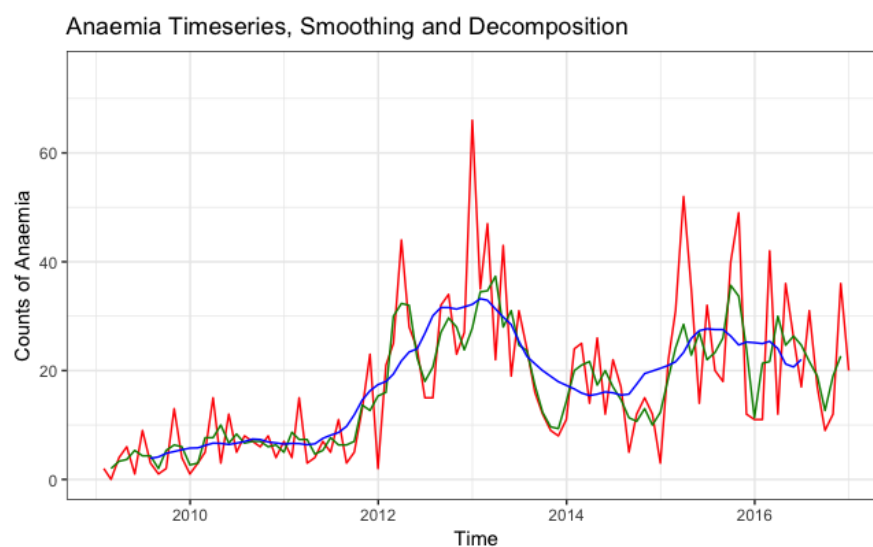


Figure 4.25: The figure shows the time series of counts of anaemia from January 2009 to December 2016, the smoothing of the series and the trend.

Figure 4.25 shows that there are ticks on the  $x$ -axis which represents the years of data recordings and the  $y$ -axis also displays the count of anaemia. The graph shows three lines which represent

the time series, the smoothing and the trend from the decomposition of the series. The red line represents the time series trend of counts of anaemia in a time series, the green line represents the smoothing of the series using the simple moving average of six, and the blue line was the trend after the decomposition of the smoothed series. The time series shows there were high counts of anaemia recorded in 2011 and 2012 and also in 2014. When the series was smoothed the smoothing showed the counts increased from mid-2011 into 2012 and onto 2013, it decreased from mid-2013 into 2014 and then it fluctuates with increasing counts in late 2015.

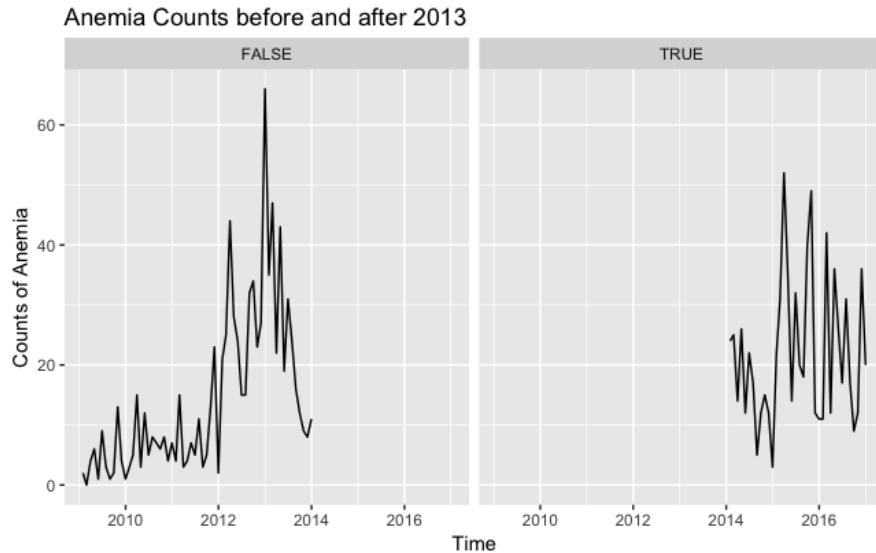


Figure 4.26: The figure shows the time series of counts of anaemia on two graphs. The graph on the left represents the the counts of anaemia before 2016 and the one on the right represents the counts of anaemia after 2013.

Figure 4.26 has on the  $x$  - axis the years and on the  $y$ - axis the counts of severe malnutrition. The patterns of counts of anaemia were fluctuating between 2009 and the middle of 2011, in the second half of 2011, the counts increased into 2012 and then decreased in the middle of 2012. The anaemia counts then increased in the second half of 2012 and rose to its peak in 2013, before gradually decreasing in 2013. In the second graph, the counts of anaemia were decreasing from the beginning of 2014 to the end of the year and then in increased at the beginning of 2015 and fluctuated until the end of 2016.

Figure4.27 has on the  $x$  - the months and on the  $y$ - axis the counts of anaemia population. The graph shows the counts of anaemia were high in some months (February - April) at the beginning of the year and at the end of the year (October and November), there were low counts in the middle of the year.

Figure 4.28 shows on the  $y$  axis the counts of anaemia after smoothing and decomposing the time series and the  $x$  axis shows the years of data collection. The anaemia trend was slightly increasing from mid-2009 to 2010 and a slight decrease in the first quarter of 2011 before in steadily increased from the middle of 2011 to its peak in the first quarter of 2013. It then decreased gradually in the first quarter of 2014 before increasing again in the middle of the year to a peak in 2015, then decreased in 2016.

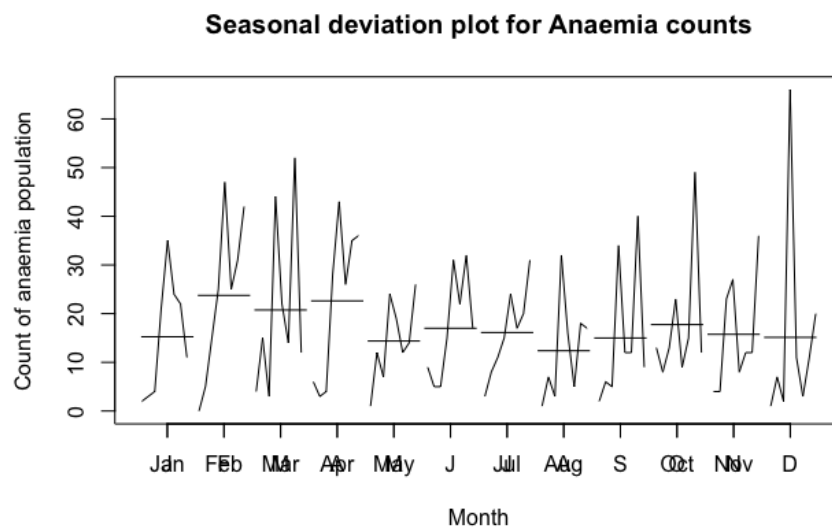


Figure 4.27: The figure shows the seasonal deviation plot for anaemia counts. The counts of malnutrition population was high in the beginning year and a slight increase at the end of the year with low counts in some months in the middle of the year .

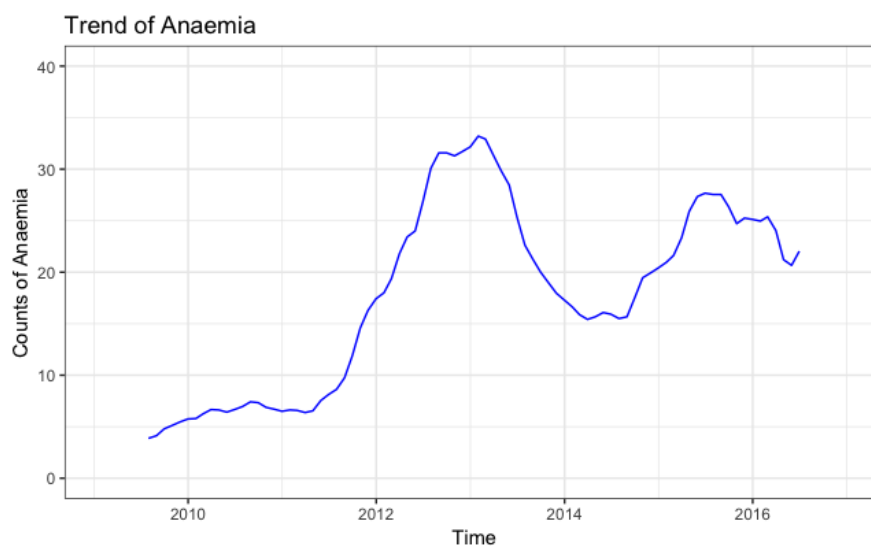


Figure 4.28: The figure shows the anaemia trend from 2009 to 2016. The trend was slightly decreasing into mid-2011 and increased into mid-2013, and then it decreased into 2014, before a slight increase in 2015. .

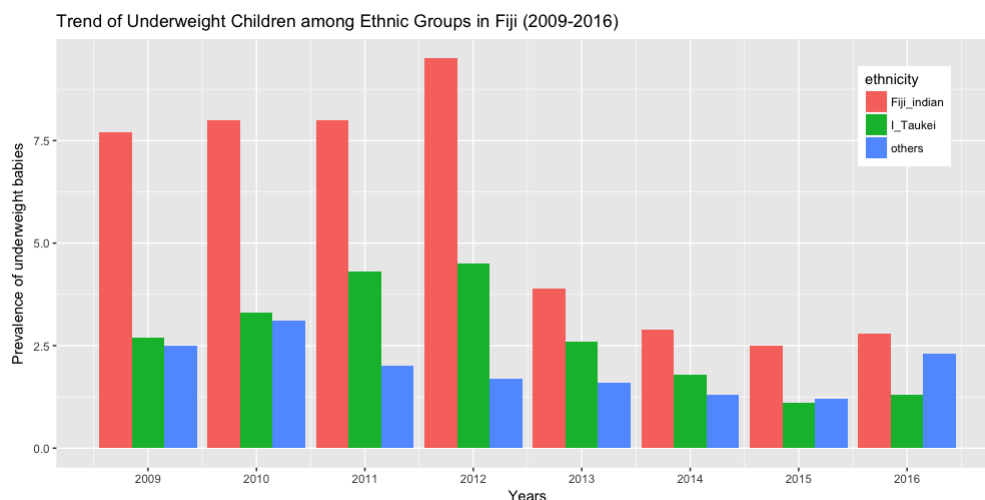


Figure 4.29: It shows the underweight children among ethnic groups in Fiji from 2009 to 2016. The prevalence of children diagnosed with underweight has been increasing from 2009 to 2012, and it decreases from 2013 to 2016. The prevalence of underweight for Fiji Indian children are more than the other two ethnic groups.

## 1.2 Ethnic distribution of Malnutrition

Figure 4.30 shows the  $x$ -axis has a tick which represents the years of the study period. The  $x$ -axis also indicates the ethnic groups in coloured bar plots where Fiji Indians are red, I-Taukei was green and other races blue. The  $y$ -axis shows the prevalence of underweight babies. The Fiji Indians recorded the highest prevalence of underweight of 9.5% in 2012, and the I-Taukei recorded the lowest prevalence of 1.1% in 2015. The general, the prevalence of underweight, began to decrease from 2012 for the Fiji Indians and the I-Taukei, and from 2012 to 2016 the prevalence declined for all the ethnic groups.

Figure 4.30 shows the  $x$ -axis has a tick which represents the years of the study period. The  $x$ -axis also indicates the ethnic groups in coloured bar plots where Fiji Indians are red, I-Taukei was green and other races blue. The  $y$ -axis shows the prevalence of growth faltering babies. The Fiji Indians recorded the highest prevalence of growth faltering of 1.1% in 2011, and the other races recorded the lowest prevalence of 0.1% in 2015. The general, the prevalence of growth faltering, began to decrease from 2012 for the Fiji Indians and the I-Taukei, and from 2012 to 2016 the prevalence declined for all the ethnic groups.

Figure 4.31 shows the  $y$ -axis as the prevalence of severe malnutrition as calculated in percentages. The graphs show there was ticks on the  $x$ -axis which indicates the years of data recordings. The  $x$ -axis also shows the bar plots along the years which represents ethnic groups in Fiji. The red plot represents the Fiji Indians, the green represents the I-Taukei, and the blue represents the other minority races in Fiji. The highest prevalence of 0.9% seen in 2012 was for the Fiji Indian ethnic group and the lowest prevalence of 0% by the other minority ethnic groups in 2009 and 2013. In general, the prevalence of severe malnutrition was fluctuating for most of the years, but it was increasing to 2012 and started decreasing from 2013 to 2016.

Figure 4.32 is the pattern of ethnic distribution of anaemia in children, it shows that there are

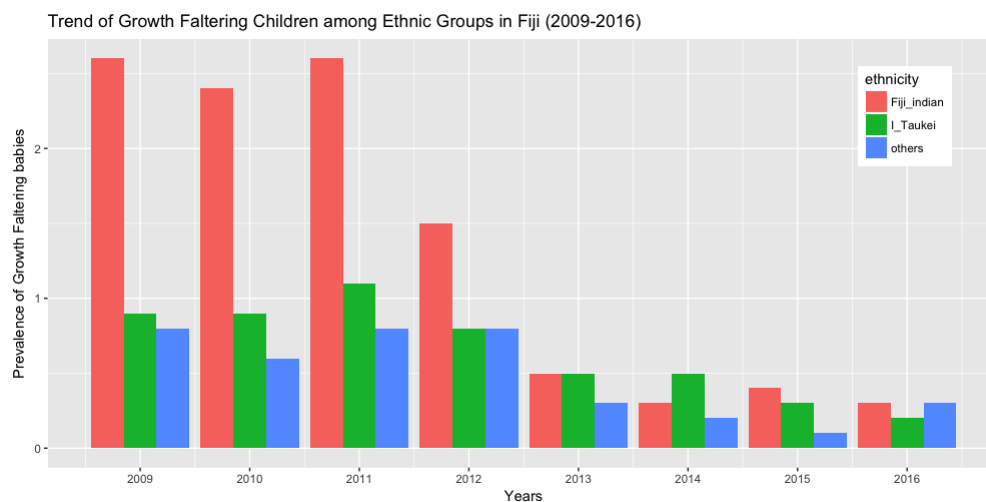


Figure 4.30: The figure shows the prevalence of growth faltering children among ethnic groups in Fiji from 2009 to 2016. The figure shows that the prevalence of growth faltering was high in the years 2009 to 2011 and decreases from 2012 to 2016. The figure also indicates that the proportion of Fiji Indian children showing signs of growth faltering was more than the I-Taukei and other minority ethnic groups.

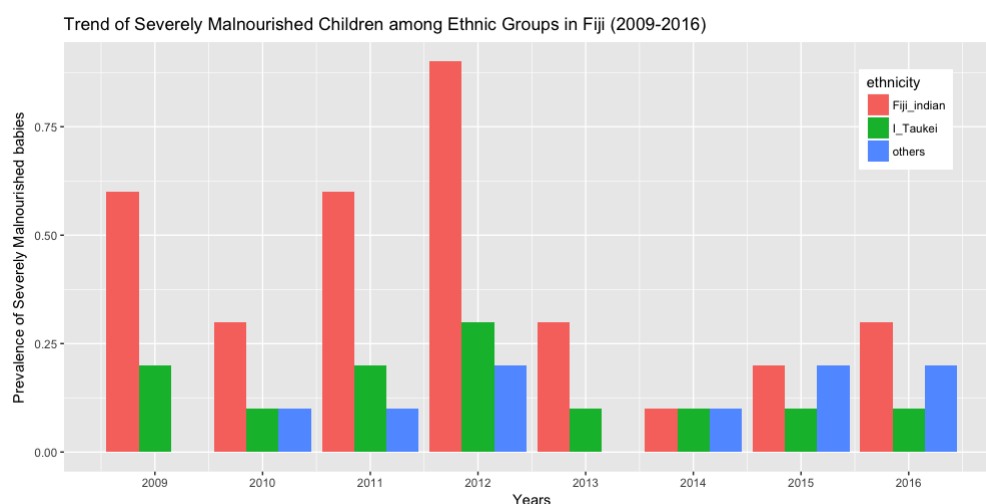


Figure 4.31: The figure shows the prevalence of severely malnourished children among ethnic groups in Fiji from 2009 to 2016. The prevalence rate of severe malnutrition reached a peak in 2012 for all the ethnic groups. The prevalence rate for the Fiji Indians was higher than the other two races.

ticks on the  $x$ -axis which represents the years of data recordings. The  $x$ -axis also displays the bar plots along the years, the bar plots represent the ethnic groups in Fiji. The red colour represents the Fiji Indians, the green represents the I-Taukei, and the blue colour represents the other minority races in Fiji. The highest prevalence of 0.8% was measured in 2016 by the other

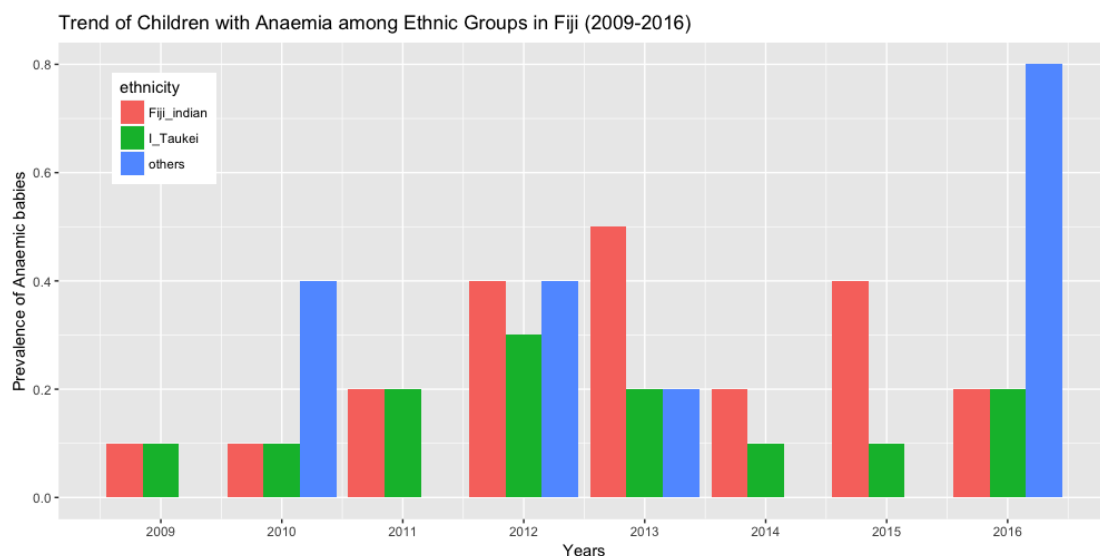


Figure 4.32: The figure shows the prevalence of anaemia among ethnic groups in Fiji from 2009 to 2016. The figure shows that the prevalence of anaemia was at its highest in 2012 for all the ethnic groups. The other minority ethnic group had significant increases in 2010 and 2016.

minority races and the lowest of 0% in 2009, 2011, 2014 and 2015. On average, there was an increase in the prevalence in 2012 where all the ethnic groups increased and a significant increase in 2010 and 2016 for the other minority races.

### 1.3 Results from Agricultural Production Variable

Year	1st Qtr (Mt)	2nd Qtr (Mt)	3rd Qtr (Mt)	4th Qtr (Mt)	Total Production (Mt)
2009	38 715.6	57 115.3	50 392.5	39 979.9	186 203.3
2010	42 354.7	44 110.7	45 273.1	60 065.1	191 803.5
2011	53 445.0	60 611.3	64 568.0	61 566.8	240 191.1
2012	32 806.0	37 748.4	37 202.3	46 160.1	153 916.8
2013	54 386.5	53 194.9	66 783.3	97 949.7	272 314.4
2014	67 723.0	67 091.1	60 322.0	58 741.8	253 877.9
2015	36 529.9	69 490.2	70 401.7	79 029.2	255 451.0
2016	58 001.7	42 224.1	62 391.7	53 428.7	216 046.2

Table 4.2: The table shows the crop production produced quarterly in Fiji from 2009 to 2016.

The table 4.33 represents crop production one of the covariate variables in the study which deals with food security. The first row was the header, and the first rows show the years of the data collection, the second to the fifth column represents the four quarters of data recordings, and the last column was the total crop produced in the year. The crop productions measurements are in metric tonnes. It was essential to include this table as food security was closely related



to malnutrition. The purpose of the table was to show the crops produced in Fiji from 2009 to 2016. The table shows that the total crop production was steadily increasing from 2009, but in 2012 it significantly dropped and it increased again from 2013, with a slight decrease in 2016.

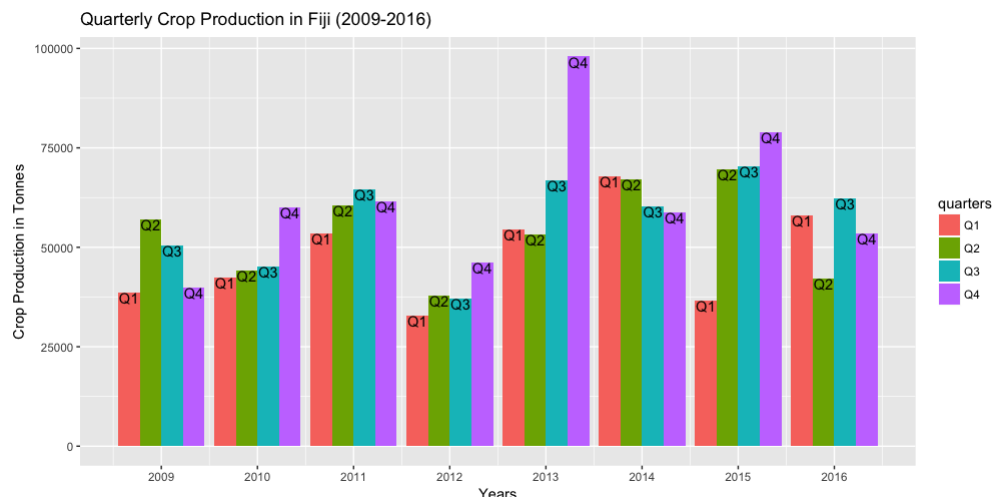


Figure 4.33: The figure shows the quarterly crop production from January 2009 to December 2016. The crop production was for all the root crops and the vegetables produced in Fiji except for the sugar cane which was recorded separately. The crop production was collected from the various divisions in Fiji.

Figure 4.33 was a visualisation of the crop production in Fiji, the  $x$ -axis shows the major ticks as the years of data collection. The  $x$ -axis shows the crop production in the bar plots for each year. In a year there are four bar plots which represent each quarter, the first quarter was represented by the red colour, the second quarter by the green colour, the third quarter by the turquoise colour and the fourth quarter by the purple colour. The  $y$ -axis shows the crop production collected in tonnes. The highest crop production of 97,949.7 tonnes was in the fourth quarter of 2013, and the lowest crop production of 32,806 tonnes in the first quarter of 2012. The crop production fluctuates up and down from 2009 to 2016. There was a cyclic pattern where it increases in one year and come down in another year and increases the third year.

The quarterly trends of crops produced in Figure 4.34 were examined using the moving average window of 4 because the crop production data were collected into quarters. The trend showed that the agricultural production decreased in the second half of 2011 to 2012 and started to improve in the middle of 2012 and continued to 2013.

## Results of Qualitative Data analysis

The second part of the results was examining available works of literature on natural disasters, policies, socio-economic and other factors associated with malnutrition.

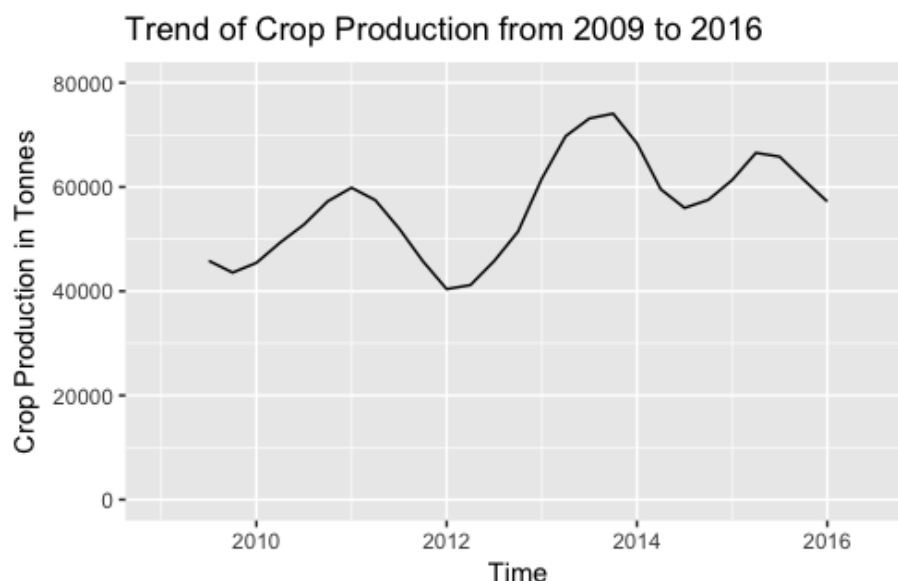


Figure 4.34: The figure shows the trends of quarterly crop production from 2009 to 2016.

#### 1.4 Extreme Weather Events and Malnutrition

The increase in the frequency and intensity of natural disasters (floods, droughts, tropical storms) due to climate change has caused many public health issues including malnutrition of vulnerable people in developing countries [Tirado et al., 2013]. As the world temperature increases, it causes more variability in the climate system that causes more extreme weather patterns from the average weather in seasons and for countries. Increase in temperatures increases the strengths of tropical storms and rainfall associated with it [Emanuel, 2000, Wing et al., 2007]. Natural disasters such as flooding, droughts and cyclones cause devastating impacts on a country's infrastructure, environment, economy, social, cultural and health status. Malnutrition was one of the indirect effects of natural disasters due to the disruption of the regular food supply to affected communities and individuals [Sharma, 2007]. It was mostly the pregnant women, children and the older citizens that are vulnerable to malnutrition [Ebi et al., 2006, McMichael, 2003]. A paper written by Tidaro (2013) discusses the fact that climate-related disasters have displaced people, causing loss of food sources and access to nutritious food. During natural disasters, vulnerable and exposed communities will be most affected. The agricultural sector was one of the hardest hit by the natural disasters. Most of the developing countries where people rely mostly on agriculture for survival have to face the consequences of the impacts of frequent disasters. Prolonged spells of droughts or floods will reduce agricultural yields and access to essential food sources was limited. The scarcity of food will cause people to eat food due to hunger and not for nutritious value. Natural disasters will damage much nutritious food such as vegetables and fruits which are rich in vitamins and minerals are good sources of iron to children and pregnant women [Tirado et al., 2013]. Keatinge et al (2010) and Gaire, et al (2016) supported the findings of Tidaro (2013) as droughts and flood exacerbate food shortages which put great pressure on the existing malnutrition status of a community or population. There are significant associations between disasters and stunting in children. The food shortages due to disasters have made food prices increase and less diversity in the availability of food. The rehabilitation phase after natural

disasters was to ensure an adequate supply of staple diet was available. Emphasis was placed on macronutrients staple diets at the expense of micronutrients diets, and this will continue the issue of imbalanced diet. The activity was more towards survival rather than promoting health [Keatinge et al., 2010, Gaire et al., 2016]. Douglas et al (2000) and Rodriguez-Llanes, et al (2012) concluded that increase wasting and stunting was evident amongst preschool children after flooding [Douglas, 2009, Rodriguez-Llanes et al., 2012]. Douglas, et al (2000) further added that the risk of malnutrition increases due to lack of coordination by South Asian governments in the distribution of rations and it leads to other social issues such as conflicts and violence due to food shortages [Douglas, 2009]. They both concluded that the low availability of existing food supplies would cause deterioration of health status of children especially those in the worse affected areas [Douglas, 2009, Rodriguez-Llanes et al., 2012]. Rodriguez-Llanes, et al (2016) in their study on child undernutrition and flooding in rural eastern India discovered that the prevalence of wasting amongst children residing in flooded communities was two times more than those in non-flooded communities. They found a significant association between flooding with wasting and underweight as compared to stunting [Rodriguez-Llanes et al., 2016]. It means that flooding causes a short-term and faster type of malnutrition which was the reason wasting and underweight increased significantly. Wasting and underweight take less time to develop as compared to stunting which was also known as chronic malnutrition. Rodriguez-Llanes, et al (2016) further added that children exposed to two floods are three times more likely to be wasted than children who are not exposed to floods and twice more likely than those exposed to only one flood. Another significant finding of his study was children less than 12 months when exposed to flooding have an average wasting which was four times higher than children of the same age in a flooded communities [Rodriguez-Llanes et al., 2016]. Another factor was that the frequency of natural disasters will force people to migrate to urban areas or another country. The new environment where people resettle often provide challenges as there will be different types of food sources, people will need to adjust to the new environment, the type of food consumed and they will need to rebuild their lives again. The children and the elderly will be the most vulnerable to the adjustment. A hurricane in 1966 caused severe damages to the island of Tokelau that lead to severe food shortages, and most of the population relocated to New Zealand under the New Zealand relocation program [Moore and Smith, 1995]. Extreme weather events happening due to the effects of climate change has disrupted crops and food supplies and indirectly increased the risk of malnutrition. Extreme weather events are one of the main factors that can affect the prevalence of malnutrition as discussed above.

## 1.5 Policies and Malnutrition

Policies refer to a set of systems and principles taken by an organisation or government to achieve a rational outcome. A policy was a statement of intent, and it was carried out in protocols and procedures. The climate change issues are well researched, and some of these have provided the basis for with the formulation of treaties and protocols such as the Paris Agreement. There were also specific research conducted by the Intergovernmental Panel on Climate Change (IPCC) and the release of assessment reports about the current and the predicted impacts of climate change. Governments need to come up with policies to address and also have specific mechanisms in place to mitigate and adapt to the different effects of climate change and in this case health effects and more specifically on malnutrition. Tidaro. M.C, et al, (2013) and Morrow, et al, (2014) state that there are climate change policies in place, but they do not necessarily address malnutrition. Undernutrition adaptation was addressed separately to agriculture, food security, social protection, health and nutrition. There was the insignif-

icant consideration of the health effects of climate change in current policies. Some low and middle-income countries lack the institutional framework to implement nutritionally based agendas [Tirado et al., 2013, Mutisya et al., 2015]. There were several policies and laws enforced in Fiji during the study period that can directly or indirectly influence the prevalence of malnutrition although, there were no specific policies that dealt with climate change and malnutrition. However, a climate change and health action plan were introduced in 2016. The *Employment Relation Promulgation* of 2007 deals with employment issues such as protection of wages, payment of workers during leave, hours of work, equal employment opportunities for men and women and a section for maternity leave [Interim government of the republic of the Fiji islands, 2007]. The law protects the worker's employment and their benefits. Therefore there was adequate income for the family during sick leaves days and also during maternity leave for the mothers. this law provides better working conditions especially for single working mothers and mothers who are the main income earner for the family, as they will be getting pay during their maternity leave. As a stable source of income will provide quality food for the family. The *Fiji Food and Nutrition Policy* of 2008 was a clear indication of concerned about the prevalence of malnutrition amongst children. The policy seeks the support of the central government in the advocacy of nutritional issues in their decision making. The policy also supports the promotion of household food security, supports healthy diets and lifestyles which can lead to an improvement of the national nutritional status. The policy pursues improvement of nutritional status for the disadvantaged in society and provides mechanisms for the implementation of nutrition policy for schools [Interim government of the republic of the Fiji islands, 2008]. The policy was looking at the vulnerable in society, and this policy addresses the issue, especially in having a nutrition policy for schools. The *National Food and Nutrition Policy for School* - 2009 was the outcome of the Fiji Food and Nutrition Policy of 2008. The policy advocates for healthy and nutritious food consumed by children in schools. It also goes further to develop a guideline for school canteens to follow on the types of food sold to students in schools [Ministry of Education, National Heritage, Culture and Sports Fiji, 2010]. Schools are where children spend much of their time during the day, and it was imperative that they be given better food choices in school. The *Fiji Plan of Action for Nutrition* or FPAN of 2010 was a working document linked to the Fiji Food and Nutrition Policy which was in alignment with the priority areas of government. The document was an integrated approach for all the stakeholders to address the issue of nutrition in Fiji. It was working on improving the weak national nutritional status as discovered in the 1993 and the 2004 National Nutrition Surveys [National Food and Nutrition Center Fiji, 2010]. As a preventative measure, the Ministry of Health *Non-Communicable disease Prevention Control: National Strategic Plan* 2010 to 2014 emphasised the need for healthy diets to be in-line with the Fiji Food and Nutrition Policy and the Food-based dietary guidelines. The objective was to improve the national nutritional status by 2014, and the program was given a budget of FJ \$80,000 budget to achieve its objectives [Ministry of Health Fiji, 2010]. The Child Health Policy and Strategy was introduced in 2012 by the Ministry of Health to improve the effectiveness and efficiency of programs and services for children to meet the MDG's related to child health. It focused on IMCI, EPI, BFHI, child nutrition, health information, research, surveillance, monitoring and evaluation. The document was needed for the ministry to refocus its services on child health as there were minor changes in the infant mortality rate for the past ten years [Ministry of Health Fiji, 2012]. In 2010 the *Marketing Control (Food for Infants and Young Children) Regulations* was enacted under the Food Safety Act of 2003. The regulation looks explicitly at the safe and adequate nutrition of infants through the promotion and the protection of breastfeeding and regulating the marketing of infant food products [Government of Fiji, 2010]. The National Health Strategic Plan 2016 to 2020 Executive Version aims to improve the relationship between the Ministry of Health personnel and the com-

munity regarding consultation and advice on proper nutrition practices and habits. The rise in the non-communicable diseases in Fiji has prompted dietitians to advocate more on the consumption of fresh local fruits and vegetables and minimise the consumption of imported food which was high in fat, carbohydrates, sugar and salt [Ministry of Health and Medical Services Fiji, 2016b]. Also in 2016, the Climate Change and Health Strategic Action Plan was launched. The plan seeks to build resilience to climate change health impacts on health through the empowerment and assistance of people through adaptation and sustainable health services. The plan focuses more on the major climate-sensitive diseases in Fiji such as dengue fever, typhoid, diarrhoea and leptospirosis and there was a brief mention of malnutrition in the plan. The findings of Morrow and Bowen, (2014) showed that the health impacts were deemed insignificant in the Fiji National Climate Change Policy, the National Climate Change Adaptation Strategy and the Public Health Act [Morrow and Bowen, 2014]. The current legislation and policies in Fiji are not seriously looking at the health impacts of climate change. However, there are some of the legislation, policies and plans introduced during the study period that can affect the prevalence of malnutrition in Fiji, that can also have an effect on the prevalence of malnutrition in Fiji. There are also social protection policies implemented by the Fijian government that may not be related to malnutrition but it has an effect on food security and reduces the risk of malnutrition.

## 1.6 Water, Sanitation and Malnutrition

Due to the warming climate precipitation levels will not be uniformly distributed worldwide, some areas will receive more rainfall and other less, therefore causing droughts and floods in different areas [Bernstein et al., 2007]. Water and sanitation are essential fundamentals in public health and the lack of these influences outbreaks of waterborne, water-based, water-related, excreta-related and toxin-related illness which has secondary effects associated with malnutrition [Montgomery and Elimelech, 2007]. The UNESCO facts and figures on water and health reported that the cause of 60% of child mortality was through infectious diseases related to water and sanitation [UNESCO, 2003]. The lack of water prevents hygienic practices, children not washing their hands after using toilets and before eating, making them vulnerable to infectious diseases [Montgomery and Elimelech, 2007]. Water shortage prevents communities from growing vegetables for proper nutrition making them susceptible to nutrition deficiencies [Keusch et al., 2006]. A study conducted in Ghana on the determinants of childhood malnutrition in Ghana found that relationship between malnutrition and diarrhoea has reduced, but it remained significantly increased when adjusted for the availability of sanitation facilities [Aheto et al., 2015]. Also in Brazil, a study by Cesar, et al (1986) found that the association between underweight and availability of sanitation facilities remained significant even after adjustment for income level. The children living in houses without sanitation facilities were three times more likely to be underweight than those from households that had proper facilities. They also found that the risk of stunting for households with access to piped water supply [Victora et al., 1986]. Abidoye and Ihebuzor, (2001) and Daniel, et al, (1991) after adjusting for confounders like socioeconomic variables, age, sex and eating habits studies have found that there was a significant association between availability of water and sanitation with stunting [Abidoye and Ihebuzor, 2001, Daniels et al., 1991]. Merchant, et al (2003) in their study found that children from homes with adequate water and sanitation would have 17% more chances of improving stunting than children from homes without water and sanitation [Merchant et al., 2003]. Water and sanitation are essential in public health, and its disruption increases risks of ill health and also malnutrition. The availability of safe and adequate water and hygienic sanitation facility will affect the prevalence of malnutrition.

## 1.7 Socio-economic factors of Malnutrition

Socioeconomic status of the child's family was a significant factor in stunting and wasting. The results of the study by Rodrigues-Llanes, et al, (2012) established that children living in the most impoverished families were more likely to be stunted as compared to those from higher-income families [Rodriguez-Llanes et al., 2012]. According to Jelliffe D B (1966), some studies have indicated that socioeconomic status was one of the contributing factors to malnutrition in children [Jelliffe, 1966]. In their study Delpeuch, et al, (2000) and Tette, et al, (2015) noted that in urban Africa wasting in children are influenced by the mother's occupation, or the monthly income of the family [Delpeuch et al., 2000, Allen and Gillespie, 2001]. A study conducted in Vietnam also found that mothers occupation was significantly related to malnutrition [Hien and Kam, 2008]. A study conducted by Irsahd.M, et al. [Irshad et al., 2014] on etiological factors of malnutrition in children under five in Pakistan found that poverty was the most common factor noted in 80% of the malnutrition cases in the study. Children living in very low food security households or low and middle income were highly likely to develop iron deficiency anaemia, stunting, wasting and underweight, than those living in high food safety or high-income households, as they cannot afford to purchase or grow their foods [Vellakkal et al., 2015]. In most of the studies conducted on the factors associated with malnutrition in children, poverty always plays a significant part, especially for developing countries. Poverty in Ghana has caused mothers to breastfeed their children longer than the six months without additional food. These children are at risk of malnutrition. It was in contrast to a study in Jamaica which shows that there was a positive correlation between the duration of breastfeeding and the child's nutritional status. The results suggest the contrast between low and mid-income countries [Melville et al., 1988, Aheto et al., 2015]. The difference here was the type, and the quality of supplementary foods given with breast milk, those in Ghana was breastfeeding for more than six months without additional food because of poverty. Children from poor households will have a higher risk of malnutrition than children from well-off households because they are highly likely to be exposed to low quality and quantity of food intake, unhygienic living conditions, more exposure to diseases and minimal or no access to essential health services [Aheto et al., 2015]. A study conducted in Vietnam showed inequality in malnutrition was due to ethnicity and socio-economic status. Since 2000 the socio-economic status of Vietnam has increased, and the prevalence of malnutrition has decreased. Vietnam had rapid economic growth and reasonable economic reforms which improved the socio-economic status and has offset the worsening malnutrition inequality. The citizens of Vietnam have been able to access quality public and private healthcare, high quantity and quality food and it was an indicator of improved socio-economic status [Kien et al., 2016]. In their study, Teixeira V H and Moreira P, (2016) found that children whose mothers had some form of employment were 57 % more likely to be overweight compared to those children whose mothers were unemployed. It shows that a good income for the family can prevent the children from underweight through the provision of adequate supply of food and accessibility to healthcare facilities. However, maternal employment can deprive the child full-time maternal care and, hinder breastfeeding and it also means, preparation of health food substitutes and reliance on others to look after the child [Teixeira and Moreira, 2016]. When there was lack of adequate care and supervision given to the child, it will increase their risk of overweight and obesity. The growth in Fiji's annual gross domestic product (GDP) can be a contributing factor to the sudden drop in malnutrition cases (low weight, growth faltering, severe malnutrition and anaemia) from 2013 to 2014. In the year 2013 there was an increase of 3.3 % and 0.9 % increase in 2014 of the GDP as shown in figure 4.35 [Reserve Bank of Fiji, nd]. The socioeconomic factor was an important component that can affect the prevalence of malnutrition. Financial status was important in providing food for the family, better housing, and water supply. As discussed above low-income families were al-



Figure 4.35: The figure shows Fiji's Annual Growth Rate from 2006 to 2016. The growth rates were negative in 2007 and 2009 and started to improve for two years before a significant decrease in 2012, and then it improved in the years after.

ways at risk of malnutrition as compared to average wage or wealthy families. A healthy national economy was important as it generates economic activity and provides for employment which relates to improving the standard of living and better food on the table for families reducing the risk of malnutrition.

## 1.8 The effects of Climate Change on Food Security and Malnutrition

Food security as agreed during the World Food Summit of 1996 was driven by three factors which are availability, accessibility and utilisation of food supply in addition to the food preference options people have for a healthy lifestyle [Pinstrup-Andersen, 2009]. The availability of food was dependent on agricultural production while the variation in food availability was linked to climate change. Climate change increases the variability of climate variables such as temperature and rainfall making the relationship between agricultural production and climate a significant concern in food security [Lobell and Field, 2007, Grace et al., 2012]. Climate change threatens food availability and disrupts food accessibility which causes poor utilisation, especially in amongst the poor communities in developing countries. Humidity and frost can affect crop production and the quality of fruits and vegetables. High and intense rainfall can damage younger plants and cause ripening grain in the standing crops, and also it increases the threat of soil erosion [Rosenzweig et al., 2001]. Temperature, rainfall, radiation and wind speed influence the growth, spread and survival of pathogens. The increase in temperature and humidity increases the spread of diseases on plants, and the wet vegetation was ideal for the growth of spores and multiplication of fungi and bacteria. Pest infestation coincides with the changing environmental conditions, and the late and early rains drought or increase in humidity can significantly reduce yields [Rosenzweig et al., 2001]. According to Bloem.W.M, et al (2009) climate change was causing an increasing demand for food supply. Variations in temperature and rainfall levels and the increase in the frequency and intensity of natural disasters are causing affecting crop production, causing a shortage in supply [Bloem et al., 2010]. Keatinge, et al (2010) found that low-income families are forced to consume low quality food, and it increases the risk

of micronutrient malnutrition [Keatinge et al., 2010]. It was supported by Park, et al (2009), Sreeramareddy, et al (2015), Vellakkal et al (2015) that children living in very low food security households or low and middle income were highly likely to develop iron deficiency anaemia, stunting, wasting and underweight, than those living in high food security or high-income households [Sreeramareddy et al., 2015, Park et al., 2009, Vellakkal et al., 2015]. Keatinge, et al (2010) further added that affected countries are cultivating food based on survival rather than on health and there was an emphasis on growing staple food than growing vegetable [Keatinge et al., 2010]. Developed countries have a variety of food choices than developing countries, but little significance was given to the production of fruits and vegetables. Malnutrition cases in Africa and Asia are increasing due to lack of food choices. McDonald, et al (2015)[McDonald et al., 2015] differed with the previous study that food security was significantly associated with child malnutrition. In their article, there was no significance between household food insecurity, dietary diversity and stunting on a study conducted in Cambodia, Southeast Asia. However, there was a significant relationship between maternal thinness and anaemia. As the severity of the insecurity increased, the maternal thinness and anaemia also increased. The authors argued that this was due to culture and traditional lifestyle within the household, that mothers nutritional needs were not as crucial as children or other members of the household. Tidaro, et al (2013), Vellakkal, et al (2015) and Keatinge, et al (2010) stated that increase in food prices was associated with child underweight. The decrease in food productions leads to increase in food prices. Therefore children's food consumption dropped significantly when the food prices increased. The constant availability of food supply was essential in food security to sustain the nutritional needs of the population especially those in the vulnerable groups (women, infants and the elderly) [Tirado et al., 2013, Vellakkal et al., 2015, Keatinge et al., 2010]. The global recession in 2008 and 2009 caused a spike in food prices globally, limiting food consumption and shifting dietary patterns to less balanced diets [von Braun, 2010]. In trying to address this issue, a study in Niger found that the distribution of food supplements and cash transfer were best solutions to mitigating mild acute malnutrition and severe acute malnutrition [Langendorf et al., 2014, Tette et al., 2015].

## 1.9 Other factors associated with Malnutrition

Other factors associated with the prevalence of malnutrition are discussed below. Accessibility to the primary health facility and primary care was also a factor in malnutrition cases. The provision of primary health care in the community significantly reduced the underweight of children in Jamaica [Melville et al., 1988]. Edem, et al (2015) in concluding their study mentioned that lack of access and provision of health services, immunisation, low birth weight, infectious diseases such as diarrhoea and developmental delay are contributing factors to malnutrition [Allen and Gillespie, 2001]. A study conducted in Iran showed that decrease in the prevalence of malnutrition was due to the increase in the accessibility to health services, increases in programs for improvement of nutritional status and promotion of public health indicators [Almasian Kia et al., 2017]. In a study on socioeconomic-related inequalities in child malnutrition in Ghana, Novignon, et al (2015) discovered that children whose mothers sought antenatal care from medical facilities had high scores for height for age which was an indicator for stunting. It was better than those children whose mothers sought antenatal care from other sources such as traditional birth care providers [Novignon et al., 2015]. Accessibility to health care was essential for pregnant mothers and babies to get medical care and advice and reduce the health risk, especially malnutrition.



### Mothers Education Level

Another factor that must be considered was the mothers educational level or her knowledge level. A study in Nepal found that higher education of mothers was closely related to reduced levels of stunting of children especially females. Stunting was prevalent amongst girls due to gender inequality as it was customary for Nepalese to favour males over females over economic and inheritance of family property. The findings of the study suggest that well-educated mothers address gender equality, care and misconceptions in their family, in the process improving the nutritional status of their daughters [Sarki et al., 2016]. In Ghana, Kenya and Bangladesh, the majority of children whose mothers had no formal education had malnutrition in the forms of stunting, underweight and wasting compared to children whose mothers had secondary school education or higher level of education [Novignon et al., 2015, Hasan et al., 2016, Grace et al., 2012]. A study by Teixeira and Moreira, (2016) had similar findings that children whose mothers had no formal education were four times more likely to be stunted than those children whose mothers had some form of formal education [Teixeira and Moreira, 2016]. Higher education gives mothers a higher level of independence, have a more significant influence in the decision making of the family in issues relating to health and accessing the available modern health facilities leading to a better health outcome for their children [Hasan et al., 2016, Kishor, 1995]. Na, et al (2015) on a study on the association between women's empowerment and infant and child feeding practices in sub-Saharan Africa found that the relationship differs from country to country [Na et al., 2015]. Economic empowerment through employment has a positive association with the infant and young child feeding practices. In the Philippines, the women's contribution to the household and the control over her income had a significant relationship in increasing household food expenses [Na et al., 2015, Schmeer, 2005]. When women have power and money the family feel secure regarding food security and well being, but this was only benefiting the older children [Lamontagne et al., 1998]. Women with secure financial status increase their chances of buying food and breast milk substitutes for her children. Working mothers may find it difficult to continue with breastfeeding or to breastfeed as frequently as they want [Hazir et al., 2013, Noble, 2001]. The other adverse effect was that well-off financial women might prioritise urgent family matters over the nutritional needs of her children [Na et al., 2015]. The father's education level also affects the malnutrition status of the child. Rayhan and Khan (2006) using logistic regression found that malnutrition rates for children decreased when their father's education levels increased. Children whose fathers attended primary and secondary level education had 0.98 and 0.70 lower risks of malnutrition than children with illiterate fathers [Rayhan and Khan, 2006]. Mothers education level was essential in making the right food choices for her child. It was also crucial that higher education will get her higher chances of employment that enables her to provide for her children. Fathers education level was also an important factor in minimising the risk of malnutrition in the household.

### Multiple Births

Multiple births are also contributing factor to malnutrition, especially underweight. An article by Justice Moses, et al (2015) found that the multiple births were a statistically significant risk in underweight, but negatively associated with stunting and wasting [Aheto et al., 2015]. The parents or guardians will need more time and proper financial support to look after their children if there are multiple births in the family. Otherwise, there would be inadequate care given to the children and puts them at risk of malnutrition and other diseases. Malnutrition status diminished with longer birth intervals, children with longer birth intervals had a lower risk of stunting and

underweight. Rayhan and Khan (2006) conducted a study on factors causing malnutrition among children under five in Bangladesh using the Cox linear regression. They found that children with 0 -23 months interval and 24 - 47 months had 1.55 and 1.36 times higher risk of stunting than children with birth intervals of 40 months and above [Rayhan and Khan, 2006]. A similar study by Mozumder, et al (2000) using cross-tabulations and logistic regression found the importance of longer birth intervals in reducing malnutrition. The study showed that an increase in the birth intervals decreases the risk of underweight, longer birth intervals reduce sharing amongst the children and also gives parents ample time to look after their children [Mozumder et al., 2000]. Mothers health are essential in minimising the risk of malnutrition or any other health issues to her siblings. Multiple births are a risk factor for malnutrition as discussed above as there will be inadequate care and attention given to her siblings.

### **Mothers BMI & Immunisation**

Other factors that can affect the prevalence of malnutrition are the mother body mass index, immunisation status of babies, low birth weight and episodes of diarrhoea. The economic stand-ings of the household influences the women's body mass index (BMI), a stable income allows for the family to have adequate meals [Delpeuch et al., 1994]. Children with malnourished mothers had a higher percentage of malnutrition than those with nourished mothers. Logistic regres-sion analysis by Rayhan and Khan S H (2006) revealed that children with acutely malnourished mothers were 62% more likely to be underweight than those children with nourished mothers [Rayhan and Khan, 2006]. Another factor that further compounds the issue as highlighted by Gaire (2016) [Gaire et al., 2016] and Rodrigues-Llanes, et al (2012)[Rodriguez-Llanes et al., 2012] was the immunisation status of children. Fully immunised children had a less likely chance of being stunted. Low birth weight and episodes of diarrhoea are also factors of malnutrition. A study in Ghana showed that malnutrition was caused by low birth weight, having episodes of diarrhoea within the six months after birth and having developmental delays. The frequency of diarrhoea can cause malnutrition to be severe in children, and this occurs due to the association between the illness and malnutrition [Tette et al., 2015]. Babies with low birth weight had a higher risk of malnutrition than children with average or higher birth weight. Rayhan and Khan (2006) in their study using the Cox linear regression found that children with low birth weight or smaller in size were 2.08 and 1.79 times more at risk from stunting than children with normal or higher birth weight [Rayhan and Khan, 2006]. Malnutrition was a complex disease, and many factors are responsible for its prevalence. However, for this study, it will look at climate change as one of the factors contributing to malnutrition.

## Chapter 5

# Discussion and Conclusion

### 1 Summary of Findings

The study found that the monthly average maximum and minimum temperature, total rainfall and monthly average relative humidity had seasonal patterns between January 2009 and December 2016 as shown by the seasonal plots in the results section. There were increases in the beginning and at the end of the year and decrease in the middle of the year, which conforms with the seasons in Fiji. The time series for climate variables were stationary. After smoothing and decomposing the time series the trend of the average monthly maximum and minimum temperatures and average monthly relative humidity did not show many variations from 2009 to 2016. However, there were variations in the trend of monthly average rainfall for the same period.

The time series for malnutrition classifications were non-stationary which means there were many variations in the data. The time series of malnutrition variables were separated, one period before 2013 and the other after 2013, where two distinct patterns were noted. A distinct pattern was seen when the time series of malnutrition classifications were divided into two, one period before 2013 and the other after 2013. Generally, there was an increase in malnutrition before 2013 and a decrease in cases after 2013. The malnutrition classifications of underweight, growth faltering, severe malnutrition and anaemia had variations between 2011 to 2013. The seasonal deviation plots showed that underweight were less in the beginning and the end of the year but increase in the middle of the year. The growth faltering, severe malnutrition and anaemia were showing different seasonal deviation where there were high cases in the beginning and at the end of the year and low cases in mid-year. The trends of malnutrition (underweight, growth faltering, severe malnutrition and anaemia) after smoothing and decomposition were decreasing from the beginning of 2011 and then made a steep increase in the second half of the year. The increase continued into the first half of 2012, and then it decreased in the second half of 2012 and continued into 2013.

The prevalence of indicators of malnutrition (underweight, growth faltering, severe malnutrition and anaemia) was high in the Fiji Indians as compared to the I- Taukei and the other races. Crop productions for Fiji decreased in the second half of 2011 and the first half of 2012 and improved in the second half of 2012 and continued into 2013.

## 2 Temperature, Rainfall and Humidity

There is not much variation in the seasonal fluctuation of the average maximum and the minimum temperature for Fiji during the study period. The temperature fluctuations are due to the seasonality of the climate in Fiji, the warm wet season and the cold, dry season. It is a typical climate variability in the tropical environment. Temperature variability in Fiji is rather small and linked to the changes of the surrounding ocean temperature, and the seasonal cycle is influenced by the SPCZ together with ENSO which has an effect of the yearly climate variability [CSIRO et al., 2011].

The average temperature increase across the Pacific is only 0.9 degrees for the last 60 years from 1961 to 2011, and the average increase for Fiji was 0.25 degrees Celsius during this period [CSIRO et al., 2015]. It suggests that the temperature is increasing, but is not seen in a short time span of ten years but over a longer time span. The seasonality patterns for the climate variables were consistent with the regular seasons for Fiji and the islands in the South Pacific, where the temperature and rainfall are high at the beginning and the end of the year and low in the middle the year. Fiji has two different seasons, the dry seasons which runs from May to October and the wet season from November to April [Sharma, 1983]. Matakai, et al (2006) stated that winter months in Fiji is also from May to October and summer months between November to April [Matakai et al., 2006].

The rainfall trend was at its peak during parts of 2007, 2008 and twice in 2012. The rainfall trend peaks were consistent with the La Nina cycle occurring in the same period. There were robust La Nina recorded for the 2007/2008 season and also a moderate La Nina for the 20011/2012 season [Null, 2018]. The SPCZ brings with it rainfall bands and influences the rainfall patterns in the Pacific. In a typical situation, the SPCZ is located to the north of Fiji and during the La Nina period the SPCZ moves away from the equator and lies over Fiji increasing the rainfall levels in Fiji [CSIRO et al., 2011]. There was two low point in the rainfall trend that was recorded in 2010 and at the end of 2015. Fiji experienced drought conditions at the end of 2015. The government of Fiji stated that the country was experiencing drought from 2013 to 2015 and was looking for responses to mitigate the effect of the drought [The Fijian Government, 2016]. The drought conditions in Fiji is confirmed by the figure 4.9 on the results showing the decrease in total rainfall. The low levels of rainfall coincided with the El Nino cycle during those years. During the El Nino years, the SPCZ moves closer to the equator taking the rain bands with it. Fiji's location is farther south from the equator, and during this period there is below average rainfall experienced in Fiji. The rainfall trend had two low peaks in 2010 and 2015, where it coincided with the El Nino event [Null, 2018]. The Australian Bureau of Meteorology states that more than 80% of drought experienced in Fiji is due to El Nino events. In the study period, there was high rainfall between 2011 and 2012 and low rainfall from 2013 to 2015, and it confirms with the predictions of CSIRO and ABM volumes one and two who predicted that the intensity and the frequency of precipitation and the SPCZ would increase for Fiji in the 21st century [CSIRO et al., 2011]. Boé, et al, (2009 ) stated that the changes in seasonal and annual rainfall vary from the changes in rainfall extremes. Climate change moves the mean rainfall totals and the distribution of rainfall such as light, low, high and dense rainfall [Boé et al., 2009]. By 2100 the ratio of heavy rain to total precipitation will increase in cyclone prone areas. The IPCC reported that maximum seasonal rains have a current probability of happening every 1-20 years, but this will occur every 1-5 years by 2100 [Bernstein et al., 2007].

The humidity trend for the study period is slightly decreasing after 2013 as compared to the years before 2013. The humidity was decreasing due to the decreasing rainfall trends recorded during

the study period. A study by Asuquo A, et al, (2013) states that there is a high correlation between rainfall and humidity. The study has revealed that relative humidity is an indicator or precursor of occurring rainfall [Umoh et al., 2013].

### 3 The seasonality of malnutrition in Fiji

The results of the seasonality plots showed that for underweight and severe malnutrition, the cases are low at the beginning and the end of the year. The growth faltering had an increase in the first month and decreased at the end of the year and the anaemia decrease at the start of the year and increases at the end of the year. One of the possible reasons for this is that most of the children clinics are closed from the end of December to the end of January, these include the IMCI clinic, the SOPD clinics, SNAP clinic, and non-thrivers clinic for malnutrition. In this study, the data collected is the consolidated data from the PHIS which includes reports from all cases of malnutrition in the district, including those seen at the IMCI Clinic. Some of these cases are reported from the IMCI clinics as children are regularly seen at these clinics. The cases for February is always higher than January as this is the time when children and mothers rush to the clinics. The other possible reasons are that this is what is known as the festive season in Fiji, and people travel during these times for family get together and functions, and children can miss clinics. Those who are initially from the outer islands usually start travelling early December after the school holidays to avoid the Christmas rush, and children miss their December clinics.

Looking the general patterns of seasonality plots of malnutrition except for underweight, have low counts of malnutrition in the middle of the year and high counts at the either at the beginning or the end of the year or both. A possible explanation is malnutrition is more prevalent in the warm and wet season and less prevalent in the cold, dry season. The warm wet session in Fiji that falls from November to April is also known as the cyclone season for Fiji. The International Disaster Database website ([www. emdat.be/ emdat db/](http://www.emdat.be/emdat_db/)) reported that between 2009 and 2016, seven extreme weather events happened in Fiji, where five of the events occurred at the beginning of the year and two at the end of the year. The two flooding events, one in 2009 and two in 2012 occurred between January and March. There were two cyclones at the at the beginning of the year and two at the end of the year and a drought at the end of 2015. The extreme weather events can increase the risk of malnutrition. Natural disasters such as flooding, droughts and cyclones cause devastating impacts on a country's infrastructure, environment, economy, social, cultural and health status. Malnutrition is one of the indirect effects of natural disasters due to the disruption of the regular food supply to affected communities and individuals [Sharma, 2007]. Rodrigues-Llanes, et al (2016) stated that children exposed to floods have a high chance of wasting than children who are not exposed to floods [Rodriguez-Llanes et al., 2016].

#### 3.1 The overall trend of malnutrition

The trend of malnutrition for underweight, growth faltering, severe malnutrition and anaemia were showing almost similar patterns where there were peaks around 2013 and dropped after 2013. The underweight, growth faltering, severe malnutrition and anaemia counts were decreasing from 2010, and in 2011 it increased in the middle of the year and then decreased before a major increase in 2012. After 2013, the malnutrition trends behaved differently for each of the classifications. The underweight has a period of stagnant counts and then a slight increase towards the end of 2015 to 2016. The growth faltering remained stable, the severe malnutrition and anaemia

increased from 2015 and 2016. The general increases after the 2012 and 2013 period was in 2015 and 2016. As mentioned above, Fiji was going through a major drought like situation from 2013 to 2015, and the worst seen in 2015. The local media were reporting that 67,000 people were affected by the drought in the Northern and the Western Division of Fiji and the Fijian government were trying to cope with the situation [Dr Sushil K Sharma, 2015, Anonymous, 2015]. The links between malnutrition and drought are complex and indirect, a study by Delbiso, et al (2017) on droughts, conflicts and malnutrition in Ethiopia found that children with wasting were 34% higher in moderate drought areas than areas without drought, but with no difference in areas without drought [Delbiso et al., 2017]. The effects of the drought on the population were not as severe when compared to the floods of 2012, as the policies in place and the introduction of other social protection programs eased the increasing count of malnutrition. The budget address of 2015, the government announced the continuation of the social protection programs such as food voucher and child protection allowance [The Government of Fiji, 2014], please refer to the appendix for the table. In 2016, Fiji experienced the worst cyclone in its history, a category five cyclone *Winston*. However, it did not have a major effect on the counts of malnutrition as the one encountered in 2012 and 2013.

### 3.2 The trend of malnutrition in Fiji 2011

In 2011 the average maximum and minimum temperature were stationary, rainfall levels increased in the first half of the year and decreased in the middle of the year and increased at the end of the year. However, indicators of malnutrition in this study (underweight, growth faltering, severe malnutrition and anaemia) were decreasing in the first half of the year and increased in the second half of the year. Based on this, it is impossible to ascertain whether the decrease in the prevalence of malnutrition is related to whether or climate variables. Malnutrition, however, did decrease in the first half of the year to its lowest point in the study period.

In the 2011 Budget address, the Fijian Finance Minister announced that in 2010 government was introducing food vouchers to those on the welfare scheme which included single mothers without employment, widows, and the elderly for the first time in Fiji's history. The scheme benefited 23,000 Fijians and government was allocating further funding to the program which would benefit an additional 10,000 Fijians [The Government of Fiji, 2010]. It addresses maternal nutrition for mothers living near or below the poverty line and also it is an additional source of food for the family if families are living with widows and elderly. The ministry of health in their 2011 annual report has stated that food voucher program was an initiative for expectant mothers in rural areas to utilise their rural health facility and attend early bookings. There was also the milk supplementation program where provision of milk powder to supplement the diets of severely malnourished children from disadvantaged families. Nuskyn company was providing free vitameal to children in Fiji as part of their "Feed the Children Initiative" to address the issue of undernourished children [Ministry of Health, 2012]. Gomez, M, et al, (2013) in their study stated that many of the developing countries are establishing food safety nets through the food assistance programs (FAP) to those at risk of malnutrition and global estimates by the World Bank state that 115 million people annually benefit from food assistance programs [Gómez et al., 2013]. Lentz, E, et al, (2013) highlighted that food assistance programs could be a practical way of tackling malnutrition [Lentz and Barrett, 2013]. Even though this program started in 2010, the impacts on malnutrition are evident, as prevalence was decreasing from 2010 onto the first half of 2011. Another possible factor cause is at the end of 2009, the Fijian government issued a decree that provided the legal framework which launched the National Employment Center whose primary objectives is to provide quality employment services to the unemployed and designing

an environment for sustainable employment [Nicholls, 2008]. In the 2011 budget announcement, additional funds were added to the centre to train and mobilise five hundred Fijians into the workforce [The Government of Fiji, 2010]. The continued funding to the centre signifies the centre was achieving its aims and objectives in preparing Fijians for employment and is one of the possible reasons for the increase in employment in 2011. The Fiji Bureau of Statistics recorded an increase in the number of people with employment in 2011 as compared to the previous year. The number of waged earners employed increased by 979, and the number of salaried workers increased by 3972 [Fiji Bureau of Statistics, 2017]. A study by Tette E, et al, (2015) in urban Africa noted that wasting in children is influenced by the monthly financial status of the family [Tette et al., 2015]. Allen and Gillespie, (2001) stated that better income at the household level leads to families spending more on food, paying for adequate and wholesome water supply and good health care. However, they argued that income growth alone not be strong enough to reduce malnutrition, as there are other avenues such as nutritional programs, micronutrients supplements and community behaviour change scheme [Allen and Gillespie, 2001]. Haddad, L, et al, (2003) conducted a study from twelve countries on household consumption and GDP with child malnutrition. They found that household and cross country levels continued growth, leads to the reduction in malnutrition. It projected that countries with a growth rate of 2.5% per year could reduce malnutrition (low weight for age) by 27% [Haddad et al., 2003]. The government enacted the Marketing Control (Food for Infants and Young Children regulations) in 2010, which emphasises at the promotion and the protection of breastfeeding and the regulating of the marketing of infant food products [Government of Fiji, 2010]. One of the objectives of the regulation was to reduce the dependence on infant formula and encourage breastfeeding for young children under six months. The regulation also indirectly supported the breastfeeding hospital initiatives by the Ministry of Health, where all hospital provide a conducive environment for mothers to breastfeed their babies. The findings of Alderman, H, et al, (2005) showed that nutrition intervention programs in the community and income growth at the household level is enough to bring the malnutrition prevalence down [Alderman et al., 2006]. The effectiveness of the food for infants and young children regulations could not be determined as the dataset given was not stratified to include the concerned age group. These may be some of the possible social factors which would have contributed to the decrease in malnutrition trend during the first half of 2011.

In 2011, the prevalence trend of indicators of malnutrition made a U-turn and started to increase towards the end of the year rapidly. As similar to above no unusual weather or climate patterns were happening to indicate the sudden increase in the prevalence of malnutrition. Some of the possible factors which would have contributed to the increase in malnutrition in the second half of 2011 are the decrease in the Fijian GDP by 0.3% [Reserve Bank of Fiji, nd], even though it is a small decrease it has an effect on the economy and trickles down to the household level. As stated by Haddad, L, et al, (2003) growth rate is vital in reducing malnutrition especially for low weight for age [Haddad et al., 2003] classified as underweight in this study. The Fijian government also increased VAT on the 1st of January, 2011 from 12.5% to 15% in 2011, an increase of 2.5% [The Government of Fiji, 2010]. The effect of the introduction of VAT took time to have its impact as malnutrition indicators began to increase in the second half of the year. The increase in VAT leads to the rise in most of the food items consumed by Fijians. The Consumer Council of Fiji released a media statement in August of 2011 stating that food prices continue to increase in Fiji. The rate for essential food items such as sugar and butter increased by 18% and 52.1% respectively. Another contributing factor to the increase in the price of sugar is the lack of supply from FSC, who is now importing sugar from Thailand to meet the local demand. The Consumer Council also highlighted in October of 2011, that liquid milk was

out of stock in most of the major supermarkets, and they were calling on the suppliers to meet the public demand as most of the milk in Fiji is imported [Consumer Council of Fiji, 2011b, Consumer Council of Fiji, 2011a]. The media (*Fiji Sun*) [The Fijian Government, 2013] have reported that liquid dairy was restored in supermarkets in September which means that there has been lack of milk months earlier. The three issues highlighted are related and are possible risk factors for the increase in indicators of malnutrition in Fiji.

Growth in the VAT can increase the price of food and reliance on imported food can cause food shortages. The results of a study by Vellakkal, S, et al, (2015) on child malnutrition and spikes in food prices in India between 2006 to 2009 revealed that food consumption of children reduced significantly across the entire population. There were variations across the different income groups, but nutritional risks were more amongst low-income children [Vellakkal et al., 2015]. Sudden increases in food price make it difficult for families to adjust, crumbling their purchasing power, minimising their calorie and nutritional intake and driving more people into hunger [Committee, 2011]. Pee, S, et al, (2010) added that during the Asian and African economic crises of the late 1990s food prices increased, household reduced their consumption of expansive foods such as meat, poultry, fish eggs, even fruits and vegetables. The next phase was they started reducing the size and the frequency of their meals. They also added that food prices are expected to remain high due to low stocks from low production, climate change and the demands of bio-fuels [De Pee et al., 2010]. The high food prices increase the risk of hidden hunger a term used to people suffering from micronutrient deficiency as it usually takes time and shows when it is severe. Hidden hunger happens when people do not have access to micronutrient-rich foods, fruits, vegetables, meat which are either expensive to purchase or are not available locally [Committee, 2011].

The South Pacific islands including Fiji are big importers of cereals, and the dependency has been increasing due to the reduction in agricultural production and the fast-moving rural to urban drift [Hughes and Lawrence, 2005]. The year 2011 was an extraordinary year for Fiji as there were two scenarios seen in the way prevalence of malnutrition occurred. Government's initiative in providing food vouchers in addition to the welfare scheme and increase in employment initially may have contributed to the reduction malnutrition prevalence. However, this was not sufficient as the increase in taxes, the reduction in the GDP, the increases in basic food prices and the shortage of some necessary food items lead to the sudden rise in the prevalence of malnutrition.

### 3.3 Malnutrition in Fiji 2012

In 2012 the prevalence of the indicators of malnutrition (underweight, growth faltering, severe malnutrition and anaemia) continued to increase until the middle of the year, and then it decreased around 2013, where it decreased further or became stagnant for some of this indicators. Our findings showed that rainfall trend was high between 2007 and 2008 and again in 2012. High rainfall occurred at the beginning of the year during the rainy season, but these peaks were above average rainfall levels. A strong La Nina occurred between 2007 and 2008 and a moderate La Nina in 2012 which are responsible for the above average rainfalls. One of the effects of climate change is the variability in rainfall patterns, as some areas will receive more and some will receive less than average rainfall [Pachauri et al., 2014]. Fiji was experiencing an active La Nina phase in 2012, and La Nina phase means more than average rainfalls for Fiji. The CSIRO and ABM volumes 1 and 2 predicted that the intensity and the frequency of the rainfall would increase for Fiji in the 21st century [CSIRO et al., 2011, CSIRO et al., 2011]. As a result, two significant floods affected Fiji in the first quarter of 2012. The first floods occurred from 21st January to



12th February affecting the western parts of the main island. The flood caused FJ \$50.4 million in damages and affected more than 178,000 people. The damage estimation assessment on the agriculture sector was more than F\$7 million [National Disaster Management Office Fiji, 2012], this is quite an extensive damage for a small island country like Fiji and is expected to affect food prices. A tropical depression TD17F caused the second flooding in the early hours of the 30th March also affecting the western parts of the main island. It was the second flood to hit this area in less than a month. The floods affected 150,000 people, and the total costs of damages were FJ \$71.2 million dollars. The damage estimates from the Ministry of Agriculture was F\$17.4 million with crop loss alone costing F\$16 million, and significant damages occurred in the Sigatoka area where 80% of the production was affected. The flood affected 12,799 farmers, both commercial and semi-commercial and flooding has caused people in affected areas to be without primary root crops and vegetables for three months. The Sigatoka farmers were supplying seedlings and vegetables after the January floods, and this flood has severely affected them [Office, 2012]. Therefore, the costs of vegetables are expected to increase drastically due to the shortage in supply.

The prevalence of the indicators of malnutrition (underweight, severe malnutrition and anaemia) in 2012 were the highest recorded than at any time during the study period. Our study findings showed episodes of high rainfall and flooding exacerbate the prevalence of malnutrition (underweight, severe malnutrition and anaemia) similar to the findings of Grace K, et al, (2012) that there was a significant relationship between seasonal rainfall and child stunting [Grace et al., 2012]. It also supported Rodriguez-Llanes, et al, (2016) findings that children exposed to two floods are three times more likely to be severely wasted than children not exposed to floods and twice more likely than those exposed to only one flood [Rodriguez-Llanes et al., 2016]. Hagos, S, et al, (2014) in their study on the effect of weather variables on child undernutrition found that variation in rainfall increases moderate stunting in different geographical zones of Ethiopia [Hagos et al., 2014]. The warming of the world due to anthropogenic climate change has caused much variability in the weather, and the increasing temperature is increasing the intensity of extreme weather events such as rainfall and cyclones. The second flooding was due to a tropical depression confirms to the study by DeMaria, M, et al, (2001) and Field, C, (2012) that warming will intensify rainfall events associated with cyclones [DeMaria et al., 2001, Field, 2012].

The other reasons for the continued increase in malnutrition prevalence were the decline in the Fijian GDP by a further 1.3% from 2011 [Reserve Bank of Fiji, nd] which means that there is a contraction in business earnings leading to consequences such as layoff from employment. Jelliffe, D, (1966) found that socioeconomic factors are one of the leading contributing factors of malnutrition [Jelliffe, 1966], in countries such as Pakistan 80% of malnutrition is due to socioeconomic factors [Irshad et al., 2014]. It is also confirmed by Haddad, L, et al, (2003), that the reduction in malnutrition (low weight for age) or underweight is dependent on the growth of the GDP of a country by a certain percentage [Allen and Gillespie, 2001]. In 2012 when crops were damaged and lost in the natural disasters, this caused a massive increase in the prices of fruits and vegetables, and the issue was compounded further by the high number of unemployment. It means that for a family living below the poverty line, they have to make do with whatever food is available to them as it becomes an issue of survival rather than wellness. The flooding affected the western side of the main island, and it destroyed the primary supplier of fruits and vegetables on the main island *Sigatoka Valley* also known as the salad bowl of Fiji. The western side of the main island was the worst affected, where damages to crops were significantly altered as the tropical disturbance brought with it flood waters which inundated standing crops [Fiji, National Disaster Management Office Fiji, 2010]. The Agriculture and Fishing Industries report compiled by the Fiji Bureau of Statistics showed a

Author (Year)	Description of the Study	Findings	
		Similarities	Differences
Grace K, et al, 2012	The research determines the relationship between climate variables and rates of childhood stunting in Kenya. Multi level regression models were used to determine the relationship.	Precipitation level has a significant effect on childhood stunting	The study uses children between 1 year to 5 years
Rodriguez Llanes, et al 2012	The study aims to understand the relationship between exposure to floods and malnutrition between 6-59 months children in rural India	Children in flooded households were more likely to be stunted than those in non flooded ones	
Rodriguez Llanes, et al 2016	The study investigated the effect of floods on the nutritional status of children from 6-59 months in Odisha, India	Severe cases of wasting was found in children who experienced flooding twice than those that experienced one flood or none at all	
Hagos,S, et al, 2014	The study evaluated the effect of weather variables on child under nutrition and the variation in effects in three areas in Ethiopia	The variation in rainfall leads to increase in moderate stunting in different areas	The increase in moderate stunting cannot be applied to all geographical zones. It differs from zones to zones

Table 5.1: *A table of works of literature that have similar or contrasting findings of the association between rainfall, flooding and malnutrition*

decline in staple crops (cassava, taro and rice) and vegetables produced in 2011 as compared to 2008, as the last data recorded in 2008 [Fiji Bureau of Statistics, 2011]. The extreme weather events indirectly affect the prevalence of malnutrition during this period as it disrupts access to medical services, especially for affected people in rural areas. The Fijian newspapers were publishing stories of flooded and damaged roads in the main centres and also in the rural areas, making it inaccessible. The Nadi International Airport was closed for four days due to the inaccessibility of the roads as tourists cannot access their hotel due to the severity of the flood [McNamara, 2013]. Accessibility is essential as it connected people to relief and medical service which is critical to the health of the vulnerable population including children, the elderly and the disabled. Studies conducted in Jamaica and Iran showed that the availability and the accessibility of medical facilities to mothers and children significantly dropped malnutrition [Almasian Kia et al., 2017, Melville et al., 1988]. Affected people are accommodated at evacuation centres for weeks, depending on the severity of the disaster in their area. The first flood occurred in January 2012, and there were 64 evacuation centres opened which were occupied by 4500 evacuees and with 42.8% of them children [National Disaster Management Office Fiji, 2012]. The second flooding was one of the worst floods experienced, there were more than 150,000 people displaced and were seeking shelter at various evacuation centres around the affected areas [McNamara, 2013]. Evacuation centres are always overcrowded, with insufficient clean water for washing, cleaning and drinking, and inadequate sanitation facilities. It creates an enabling environment for outbreaks of communicable diseases and illness, such as typhoid and diarrhoea. A study in Ghana found that there was a relationship between diarrhoea and malnutrition, even though it has reduced it remained significant when adjusted with the availability of sanitation facilities [Aheto et al., 2015]. People are provided with food rations from the government when billeted at the evacuation centre. The quotas are mainly food for adults, and there is little consideration to the types of food in the ration suitable for children. There was prioritisation of other household needs ahead of children's welfare and the limitation in the availability fresh fruits and vegetables for a healthy diets [Aheto et al., 2015]. In the floods of 2012, UNICEF was assisting in the form of water containers, water purification tablets and oral rehydration salts [National Disaster Management Office Fiji, 2012], while government and the private sector were distributing food aid, but there were no records on the type and the quality of food distributed. In times of crisis such as floods, affected people are always content with free food issued to them without being aware of the quality of these foods as their primary concern is survival. The ministry of health reported that they continued with their intervention programs such as national iron and micronutrient supplementation, the continuation of the "feed the children initiative" the provision of milk powder for diet supplements to severe malnourished children from disadvantaged families and the celebration of the national nutrition month [Ministry of Health, 2013].

In the second half of 2012, the prevalence of indicators of malnutrition (underweight, growth faltering, severe malnutrition and anaemia) decreased at almost the same rate of increase at the beginning of the year. The prevalence of malnutrition subsequently reduced after the disaster. The collaboration and partnership of international aid, the private sector, NGO's and civil society working together in the relief efforts was one of the reasons for the sudden decline in malnutrition. Australia, New Zealand and other countries assisted in the relief efforts and supported the mechanism on the ground to efficiently carry out the relief efforts. The WHO and the UNICEF provided support to the MOH through the issuance of disinfectants, rapid test kits for water, dengue and leptospirosis. They also offered drinking water containers, water purification tablets, and oral rehydration salts. The business houses contributed in cash, food supplies, agricultural equipment, and seedlings to affected communities. The government also waived two months land rentals on all crown leases [National Disaster Management Office Fiji, 2012].

The Ministry of Agriculture distributed seedlings, cuttings and assisted in the land preparation and the government has distributed more than FJ \$1 million in food rations both the floods [The Government of Fiji, 2012b]. The United Nations Development Program supported women market vendors in the Western division of the main island with the cash for work initiative. The program exchanged money for work conducted to the recovery and disaster preparedness, and it benefited more than a thousand women and indirectly helping the broader communities in flood-affected areas [UNDP, 2012]. Devereux, S, (2007 ) expressed that food aid is vital in reducing the household vulnerability to malnutrition after a natural disaster. Food rations are better than cash because it directly improves the sanitation status of the household and it is better utilised as it is controlled by women. However, the limitation in food rations is the freight costs which sometimes is more than half the value of the food aid. Food rations are better when it is sourced from the local markets to reduce the transportation costs [Devereux, 2007]. The prevalence of malnutrition after floods in Bangladesh is similar to Fiji as it also subsequent decreases after the floods. Bangladesh requested assistance from the IMF and adjusted the economy, and they made food, drinking water, medicines and shelter available to the poor [Shah, 1999]. The government also increased funding to the WAF to improve and provide safe and consistent water supply to the Fijian people [The Government of Fiji, 2011]. A study in Brazil by Victoria, G, et al, (1986) found that having access to piped water supply reduced the risk of stunting [Victoria et al., 1986]. Daniel, L, et al, (1991) in their study after adjusting for confounder has found that water and sanitation are significantly associated with stunting [Daniels et al., 1991]. Merchant, et al, (2003) found that children living in homes with adequate water and sanitation had 17% more chances of improved stunting than those living without it [Merchant et al., 2003]. The accessibility to a safe and adequate water supply is vital to improving overall health in the household and notably reduce the risk of malnutrition to children. In 2012, the Ministry of Health introduced the Child Health Policy and Strategy to improve the effectiveness and efficiency of programs and services for children to meet the MDG's related to child health. The policy and strategy specifically targeted the IMCI, the expansion program of immunisation, the baby friendly hospital initiative, child nutrition, health information, research, monitoring and evaluation [Ministry of Health Fiji, 2012]. The policy might not have an immediate impact, but it can contribute to the reduction in malnutrition in future years for Fiji. The government reduced the import duty on fruits and vegetables not grown locally. Increased funding for the food voucher program to cater for the disadvantaged school students, rural pregnant mothers and the elderly [The Government of Fiji, 2011]. The reduction in import duty for fruits and vegetables is vital as it can supplement the local produce destroyed during the floods.

### 3.4 Malnutrition in Fiji 2013

In 2013 the prevalence of underweight, growth faltering and severe malnutrition decreased and became stagnant while the prevalence of anaemia started to decrease. The decrease in malnutrition in 2013, is that the country's Gross Domestic Product (GDP) has increased by 2.5% in 2013 [Fiji Bureau of Statistics, 2017]. Ruel, M, et al, (2013) found that the prevalence of underweight in children and the growth in the GDP is compelling for underweight than for stunting, where a 10% growth in GDP will have 7% decrease in underweight. The growth in the GDP on nutrition is a combination of improved household resources, better infrastructure, and better nutrition services [Ruel and Alderman, 2013]. However, anaemia decreases at a measured rate where the 10% growth in GDP will only have a decrease in child anaemia by 2.4% [Ruel and Alderman, 2013]. Strauss and Thomas, (1995) found that reduction in poverty will lead to the reduction in malnutrition [Strauss and Thomas, 1995]. The household income

and expenditure survey conducted by the Fiji Bureau of Statistics revealed that the incidence of poverty has decreased from 31% in 2008-2009 to 28.1% in 2012-2014 which is a 2.9% decrease in poverty [Fiji Bureau of Statistics, 2017]. More income means families can now spend more on food consumption, utilise clean water and better sanitation services, and accessibility for effective child management. Communally more income leads to better accessibility and affordability to health services and better water and sanitation facilities [Allen and Gillespie, 2001]. However, income growth's role in reducing poverty is not reliable according to a study by Hadad, et al. 2003, it suggested that an increase in the number of nutritional intervention programs can reduce malnutrition [Haddad et al., 2003]. There were also some policies introduced in the years before 2013. The Fiji Plan of Action for Nutrition or FPAN introduced in 2010 as the result of poor nutrition status discovered during the National Nutrition Surveys of 1993 and 2014. It takes a few years for the policies to be implemented efficiently and its impact materialises in the country. The FPAN is a holistic approach as it starts from advocating nutritional issues from the government decision-making level right down to the household. It emphasises on the improvement of the socially economically disadvantaged, and the nutritional disadvantage groups such as children, mothers, the elderly and those living with HIV and AIDS [National Food and Nutrition Center Fiji, 2010]. The Marketing Control (Food for Infants and Young Children) Regulations enacted in 2010 looks explicitly at the safe and adequate nutrition of infants through the promotion and the protection of breastfeeding, as well as regulating the marketing of infant new food products [Government of Fiji, 2010]. The government has budgeted F\$2 million for the purchase of childhood vaccines and has also increased the WAF budget by F\$3 million more than the previous budget to expand and provide safe and adequate water to all Fijians [The Government of Fiji, 2012a]. Feller, et al, (2012) in their RCT study found that diarrhoea is always associated with malnutrition and vice versa and the use of pentavalent rotavirus vaccine did not have an impact on the malnutrition status of children after two years post vaccination. The rotavirus impacts short-term growth in children under 24 months but children who were sick with episodes of rotavirus gastroenteritis by two to three years had improved on their nutritional status [Feller et al., 2012]. The government in 2013 introduced the national pension scheme where people above 70 years receive monthly pensions. The introduction of the poverty benefit scheme, where a maximum of four people in the same household can receive assistance and food voucher. The government introduced the care and protection allowance for single mothers, deserted spouses, widows and prisoners dependents [The Government of Fiji, 2012a]. These are social protection programs introduced or supported by the government through increased funding in 2013. According to Lentz and Barrett, social protection programs are usually used to target to improve the standard of living and not on nutrition, even though the primary aim is minimising poverty it usually results in enhanced food security, health and education [Lentz and Barrett, 2013]. The government introduced a zero duty on farming implements, including seedlings and fertilisers to help farmers increase agricultural production [The Government of Fiji, 2012a]. The increase in crop production makes food readily available and also drives prices down as there is much supply to meet the demand. The Ministry of health continued with some of its programs such as the Baby-friendly hospitals, the infant and young feeding program, the vital meals to compliment children feed, milk supplementation program to aid disadvantaged and malnourished children and the national iron and multi-nutrient supplementation programs [Ministry of Health, 2014].

### 3.5 Distribution of Malnutrition

There is also variation seen in the ethnic distribution of malnutrition during the study period. The prevalence trends of underweight, growth faltering, severe malnutrition and anaemia, in general, were showing that Fiji Indian children were having high prevalence rate, followed by the I-Taukei children and then the children of other races. A retrospective study on malnutrition in Tavua Subdivision Fiji from January 2010 to April 2012 found that I-Taukei children had a higher prevalence of underweight cases than Fiji Indians and other ethnic groups. However, they discovered that Fiji Indian children between birth and six months had a higher prevalence of underweight while the I-Taukei children had a higher prevalence of underweight from 7 months onwards. The prevalence of underweight of Fiji Indian children was because of their low birth weight [Atalifo et al., 2016]. The National Nutrition Survey of 2004 showed that for every I-Taukei baby born with low birth weight there would be 2 Fiji Indian babies born with low birth weight [National Food and Nutrition Center Fiji, 2010]. The prevalence of underweight in I-Taukei children was due to the poor quality of supplementary diets and late weaning period [Atalifo et al., 2016]. The scenario in Tavua is insignificant as it is a small town with a small population and it would not be a real representative of the prevalence of underweight distribution amongst ethnics groups in Fiji. However, this is a finding, and this research cannot determine these findings as the dataset for the age category was not available. The results of the National Nutrition Survey of 2004 showed that Fiji Indian children of both genders had high prevalence low birth weight for children below two years. The Fiji Indian males had 14.3%, and females had 25.8% compared to the I-Taukei males 6.5% and female 8.8%. Some of the reasons for the differences in the prevalence of low birth weight include poor maternal health, inadequate maternal diet, lack of ante-natal facilities and expectant mothers not utilising the available services [Schultz T. J et al., 2007]. The National Nutrition Survey further discovers that the introduction of supplementary foods to the two ethnic groups vary a lot. More Fiji Indian babies are given additional foods before six months, and milk is continued to be given until twelve months or more while from six months to two years more supplementary meals are offered to I-Taukei babies. This reason given is that milk is a customary diet in a Fiji Indian traditional diet and not as an I-Taukei typical diet [Schultz T. J et al., 2007]. Another reason why more Fiji Indians are malnourished than I Taukei is that average costs of meals of Fiji Indians are more than the I Taukei [Goodall et al., 1973]. Indigenous people are more closely related to their environment, as they are more familiar with the weather and food sources, changes in weather in their environment affects their ability to adapt. Minority ethnic groups are also vulnerable as they reside in locations and have limited access to benefits from the legal and institutional systems. In India, a minority group with a population of 170 million known as the Dalits are excluded physically, socially and economically from society, and they reside in monsoon flood-prone areas [Baird, 2008]. Nutritional status differs in different ethnic groups due to dietary patterns, lifestyle, cultural and religious beliefs and socio-economic status [Chen et al., 2012]. Dietary intake and an ethnic study conducted in Malaysia found that differences in sociocultural in regards to food preferences caused differences in their nutritional behaviour [Abdullah et al., 2016]. Fiji is a multi-ethnic country with the majority of the population native Fijians called the I- Taukei and the other dominant group are Fijians of Indian descents while the other races are other Pacific Islanders, Asians, and other minority races. The differences in malnutrition of ethnic groups are not related to climate change but more from the influence of social issues.

## 4 Agricultural Production

The agricultural crop production is showing a cyclic pattern, and there are a crest and a trough in production seen from 2009 to 2016. However, the trough of 2011 and 2012 and the crest in 2013 is more than those in the other years. The drop in the agricultural production in 2011 recorded by the Fiji Bureau of Statistics from statistics supplied by the Ministry of Agriculture. There was a decline in production of major crops such as taro, cassava and assorted vegetables. In 2011 the export price of taro to Australia and New Zealand dropped, and farmers have been suffering. Taro beetles (*Papuana unidosis*) outbreaks are occurring in Fiji in 2011 affecting the production of this crop. Taro beetle was found on the island of Gau, and the Ministry of Agriculture is trying to contain the outbreak on the island. Taro beetles were found on the majority of the farming regions in Fiji in the past, and the reemergence of the pest could damage the taro industry. Taro is one of the agricultural main root crop export commodity to Australia, New Zealand and the United States and also one of the staple diets of the I-Taukei. Pests and weeds affect crops in many ways from

“ reducers (damping-off pathogens), photosynthetic rate reducers (fungi, bacteria, viruses), leaf senescence accelerators (pathogens), light stealers (weeds, some pathogens), assimilate sappers (nematodes, pathogens, sucking arthropods), and tissue consumers (chewing animals, necrotrophic pathogens)” [Oerke, 2006].

Oerke, E, (2006) state that pests in the forms of weeds, animal, pathogens continue to reduce the crop production worldwide. The losses in the agricultural production are high in the tropics in the subtropics where the weather is conducive to the pests to carry out their function. In areas where there is excessive use of pesticides the pests have developed resistance, however, this has not been proven to cause the decrease in crop production [Oerke, 2006]. The drop in the agricultural production in 2011 was from the taro beetle outbreak which affected production and also causes a drop in the export price. There are also other agricultural commodities that declined during this period which included cassava and other assorted vegetables.

The drop in the agricultural production in 2012 at the beginning of the year coincided with two major floods and a cyclone. There were two episodes of flooding experienced in 2012, one was in January where the entire western part of the main island *Viti Levu* was affected and the other in April also affecting the western division of the main island. Two significant flooding in Fiji in January and March 2012 was associated with a tropical depression. The country was receiving more than average rainfall for the three months beginning from the middle of January which caused widespread flooding and caused a state of emergency. The estimated costs to the January flood was FJ \$40 million [Kuleshov et al., 2014]. The January floods caused more than F\$8 million in damages to agriculture in the Western division affecting more than 4,500 farmers [United Nations Office for the Coordination of Humanitarian Affairs, 2012]. Two months later the most significant flood in Fiji's history regarding magnitude and damages in infrastructure. A tropical depression TD17F was moving over Fiji momentarily slowed on the Western side of Fiji, and it caused torrential and high-intensity rains which again flooded the western part of Fiji. The estimated damages of the March 2012 flood was FJ \$70 million [Kuleshov et al., 2014]. The western division has one of the most significant agricultural production areas in *Sigatoka* which is known to Fijians as ‘the salad bowl’, it mainly produces fruits and vegetables for the markets in the main towns and cities in *Viti Levu* and also for export. The Ministry of Agriculture has estimated that the costs of damage to agriculture from crop loses are F\$16 million. The flood affected the Sigatoka Valley where 80% of the crop was affected, and according to the Agriculture Ministry, this has affected the worst affected areas as it will take three months for

supply to recover [UNOCHA, 2012]. The impact of flooding and drought in Malawi reduced the national harvest and lengthened the food recovery by a few months [Devereux, 2007]. Eni, et al, (2011) in their study found that some crops are tolerant to flooding and can manage for a few days of flooding, but the majority of crops such as vegetables, tomatoes and cucumbers cannot tolerate a couple of days of flooding, it causes deaths to these plants. Plants also suffocate and die when flooded as free moisture reduces the oxygen content in the soil affecting root respiration, it increases carbon dioxide, methane and hydrogen which suffocate the plant to death. Floods always remove topsoil from farms, top soils are essential for farmers as it contains organics and minerals that aid crops to produce better yields [Eni et al., 2011]. Natural disasters such as flooding, droughts and cyclones are affecting crop production in Fiji, and it is the resilience of the farmers and the collaborative efforts of all stakeholders that makes recovery efforts productive and successful.

The agricultural production started to recover in the second quarter of 2012 and increased in the third and fourth quarter of the year. The quick recovery of the crop production is due to the rehabilitation program where the Ministry of Agriculture focused on the supply of vegetable seeds and other early maturing crops [United Nations Office for the Coordination of Humanitarian Affairs, 2012]. In the April flood, the Agriculture Ministry cleared debris and silts from farmlands, cleared drains and the distribution of seedlings [UNOCHA, 2012]. The Fijian government increased funding to the agriculture ministry in 2012 by an additional F\$15 million. The additional funding was directed at the acceleration of agriculture diversifying programs, the promotion of food security, and facilitation of partnership with the private sector [The Government of Fiji, 2011]. Dorosh, P, et al, (2010) stated that partnering with private sectors is a useful component of rehabilitation efforts through the provision of seeds, tools and technical expertise [Dorosh et al., 2010]. The role of NGO's in Bangladesh was vital in rehabilitation efforts through the affect communities through supplies of seedling and livestock to farmers to help them recover [Shah, 1999]. Dorosh, P, et al, (2010) further added that the provision of assistance such as seedlings as well as restocking the livestock to affected people could help them get back with their daily life in the medium term. The support for rehabilitation of small-scale agriculture is critical as well as duty exemption on agricultural machinery and technological advances in multiple cropping methods [Dorosh et al., 2010]. The traditional beliefs of Bangladeshi that flooding renews the soil and result in a good harvest and the rice harvest after the 1999 floods were one of the best harvests that exceeded the governments harvest projections after the flood [Shah, 1999].

In 2013, Fiji did not experience any extreme weather event, and the weather was favourable for farmers and their crops as productions continued to increase. Weather have different effects on different crops such as the rainy conditions are suitable for rice yields. Crops are also affected by unfavourable weather as too much rain, or very little rain can affect the crop yields [Iizumi and Ramankutty, 2015]. The increase in the crop yield coincided with the opening of the new sealed 15 kilometres Sigatoka Valley road, and this is the main road to the Sigatoka Valley which connects all the farms in the "salad bowl of Fiji". New roads or improvement of roads increases agricultural supplies and markets, access to better farming technologies and fertilisers and also decreases post-harvest crop loses [Laurance et al., 2014]. In 2013 the government introduced the zero duty in agricultural farming implements which included seedlings and fertilisers [The Government of Fiji, 2012a]. Standard Concrete started to manufacture agricultural lime made from pulverised limestone which increases the acidic pH of the soil [The Fijian Government, 2013]. The availability of this soil additive locally benefits the farmers as they can easily access it at an affordable price. The favourable weather, the improved road conditions, the government's assistance and the availability of soil additive locally all contributed to the improved crop production output in 2013.



## 5 Mitigating & Adapting to the Effects of Climate Change

The Fijian people have been exposed to severe weather events since they were born. The island's location makes its population vulnerable to the manifestation of extreme weather events such as flooding, cyclone and droughts. Majority of towns and cities are located near a river or the sea, as this was a major transportation route in the early days, however, in the present time, the location increases the risk of flooding, storm surges and sea level rise. The Fijian people and the government have been adapting to climate change over the years, hence the setting up of the National Disaster Management Office ("NDMO") and the climate change unit within the Ministry of Economy. The NDMO operates under the National Disaster Management Act and coordinates disaster activities through the Commissioners office in the division. The NDMO carries out activities such as disaster preparedness, mitigation, response and rehabilitation programs [The Government of Fiji, nd]. The NDMO is influential in the coordination of all stakeholders (local and international) before, during and after disasters to ensure that the safety of the population. The NDMO can advise on the areas to be declared and the time frame for a state of natural disaster, where all the government machinery will work towards recovery and rehabilitation process. In this way, it gives more time for the government to help those in rural and remote areas of the country and to ensure people recover as quickly as possible. During the January floods of 2012, the NDMO coordinated the response and rehabilitation efforts. The National Emergency Operation Center was activated, the number of evacuation centres noted, rations distributions well managed (domestic and international aid), UNICEF, WHO, the ministry of health, ministry of agriculture delivered their services to affected areas. The government understands the issues that arise after such events, and it has developed procedures and programs in place to address it. It includes, the Ministry of Health conducting environmental health works, distribution of water purification tablets and water storage containers, nurses carry out immunisation, medical check-up, the water authority check the status of water supply, the agriculture carry out their assessment and conduct rehab works such as supplying of seeds and land clearing. All of the government ministries are working together to help in minimising the outbreaks of health issues such as malnutrition. The people in the community are also aware of the locations of evacuation centres in time of emergencies. Evacuation centres are identified by the government and are public buildings such as schools, community halls and churches provide shelter during natural disasters. The Ministry of Health do carry out auditing of their health facilities to make sure that they are ready to provide service during natural disasters.

The rations that were distributed by the government, those from the NGO's and international partners included infant food, as well as diapers and sanitary packs for children and girls, and it also included vitamin tables. Some of these items for being given out for the first time during a disaster response in Fiji in the 2012 flooding events. It shows that the government and aid donors are recognising the importance of child health during extreme weather events.

As stated above, the country has adapted to the frequent adverse climate events and had structures and procedures in place to minimise the effect on the people. The Fijian government is committed to adapting and mitigating the impacts of climate change as the Prime Minister became the President of the 23rd Conference of Parties ("COP 23") in Germany in 2017. Some of the mitigation factors taken by the government was working UNFCCC on the REDD + initiative. The adaptation measures are building of sea walls in coastal communities to prevent coastal flooding and relocation of communities vulnerable from sea level rise, these are known as reactive adaptation.

The Fijian government had a good adaptation policy in place where it has been introducing

a couple of social protection programs to help the vulnerable in society. The introduction of food vouchers in addition to the social welfare voucher is a bonus to the underprivileged in the society that is most affected by the natural disasters. The introduction of the care and protection allowance for single mothers, deserted spouses, widows and prisoners dependents, and the allowance given to mothers in the maritime and rural areas when they come to the urban hospitals to deliver all contribute directly and indirectly to maternal health. The vita-meals compliments to children feed and the milk supplement to aid disadvantaged children, and the implementation of the multi-nutrient supplementation programs helped in reducing the risk of malnutrition [Ministry of Health, 2014]. Ministry of health policies, programs and initiative like the breast feeding hospital initiatives, the EPI and the *Marketing Control (Food for Infants and Young Children) Regulations* play an instrumental role in having the Fijian people adapt and build resilience against impacts of climate change that increases the risk of malnutrition amongst children from birth to five years.

## 6 Challenges and Limitation

There are some challenges experienced during the study. The classification of malnutrition in Fiji has changed between 2006 and 2016. From 2006 to 2008 malnutrition was classified as mild, moderate and severe for weight for age measurement or underweight. Then in 2009 to 2012, the classification changed to low weight, growth faltering, severe malnutrition, severe anaemia and anaemia, the only change in the classification from 2013 to 2016 was that there was no classification for severe anaemia. According to the personnel at the Ministry of Health Information unit, the changes in classification is through the recommendations of the WHO. It made it difficult to have a consistent measurement of the different classification of malnutrition during the study period.

Another limitation is the data storage system has also changed in the last ten years. It caused difficulties in extracting the dataset. It led to the next restriction where it was difficult to calculate the prevalence rate for underweight from 2006 to 2008 as the data for the total number of children seen at the IMCI Clinic was not available. The third limitation is determining the prevalence trend of malnutrition in gender cannot be done for the study period as the dataset given, only contained the ethnic distributions. The Ministry of Health Information Unit (MOHIU) did not capture the gender distribution from 2006 to 2016. The age groups of the children with malnutrition were not broken down into age categories. It would be useful in determining the effectiveness of policies such as the Baby Friendly Hospitals, breastfeeding month program and the introduction of the Marketing Control (Food for Infants and Young Children) Regulations.

The poor quality of data available from their respective sources. One of the covariates of the study is the availability of water and sanitation. The Environmental Health Unit at the Ministry of Health and Medical Services released this dataset. The water and sanitation dataset cannot be used in the study as there was no consistency shown during the study period. There was a time where missing data was for a four year period. The availability of water and sanitation was needed to be adjusted to the explanatory variable in the model to determine if it affected the outcome. The weak data quality is from the Fiji Bureau of Statistics on the socioeconomic factors such as the type of employment during the study period, and there were gaps in some of the years and therefore could not be used in the model. The education level dataset that was needed as part of the socioeconomic factors and it was not available, despite numerous attempts

to retrieve this dataset from the Ministry of Education.

This study had to go through two ethical process approval. The first is the ethical process from the Ministry of Health and Medical Services in Fiji because the researcher was collecting data from the Health Information Unit within the ministry and ethics approval is a requisite for obtaining the dataset. The process took about five and half weeks to be approved. The approval of this ethics is then submitted again to the UC ethics committee for their approval, and it took another two weeks to obtain the approvals. Altogether both the ethics approval process took almost two months to achieve. Once the ethics were approved, then the actual field work began. The other challenge is the timeline from the other government ministries in replying to request for obtaining data from them. Some government departments were very responsive. Otherwise, other ministries were very slow in responding while others did not respond at all. However, this was not from the primary data sources but those that have the covariates data. The datasets that would affect the outcome variable when adjusted in the model.

In data collection, the primary challenge is the underreporting of malnutrition cases from the medical facilities that report them to the national database. There are months and years where there are no cases reported from some of the health facilities, and within a specified period, there are many cases reported. In the dataset from 2009 to 2012 for one district in the central division in 2009 nine reporting facilities were reporting on malnutrition on a monthly basis but in 2013 onwards the same district was reporting only on three zones. There is an issue here, and the first one is that the district reporting system has consolidated the figures from the small zone into the three central zones and reported it to the MOHIU, the second one is there was no reporting. The issue of consolidating the figures at the district level is that there can be errors in data entry and can cause underreporting. From the facility level, the raw data is sent directly to the national level, and it is also easy to determine the locality if there is an outbreak. The classifications of malnutrition changed in 2009 from the ("NCHS") to the ("WHO"), there were still some health facilities that are still using the NCHS classifications, and this was noticed during the survey after the cyclone Winston in 2016. It could have led to the inconsistencies in the malnutrition cases reported, especially from the maritime zones.

## 7 Conclusion

Malnutrition is a complex and multidimensional health issue with many associating factors. This study investigated, the effects of climate change through its indicators (average minimum and maximum temperature, average rainfall and humidity) and whether it affected the prevalence of malnutrition in Fiji. The average minimum and maximum temperature did not show much of a variation, but there was variation in the rainfall levels. The slightest increase in temperature causes variability to the already fragile climate in Fiji and the Pacific due to the climate phenomenon such as the South Pacific Convergence Zone, the El Nino Southern Oscillation and the Intertropical Convergence Zone affecting the Pacific. There is no clear linkage between the effect of climate change on the prevalence of malnutrition in Fiji, as there are many social factors that cause the variation in the prevalence of malnutrition. However, the increase in rainfall intensity and episodes of flooding due to climate change exacerbates the prevalence of malnutrition in Fiji. The study found the current policies in Fiji are counteracting the effects of climate change on malnutrition. Even though few policies are directly related to preventing the risk of malnutrition, the social protection programs are affecting the prevalence of malnutrition.

Climate change risks will be more and more severe in the years and decades to come, but

effective government policies can buttress the effect of climate change. The study found that sound government policies that can withstand the impact of climate change as shown here in the case of Fiji. Government policies have significantly impacted climate change on human health especially on malnutrition. Climate change was superimposed on some economic measures that government has taken and as a result, two things worked against each other. On the one hand, the climate variability leads to the reduction in crop production which increases the risk of malnutrition, but because of government policies in place, malnutrition levels were decreasing. When the government reversed some of its policy the impact of weather was felt, and malnutrition rates increased. However, the changes in weather will only last for some time, and because of the policies in place it eventually decreases. Resilience public policy build resilience in the country and how this resilience is transferred to the community is essential. Resilience in the forms of technological mitigation through the building of cyclone resistance houses, or acknowledging that climate change can interfere with public health and know that there are active public policies that can fight the temporary effects of weather variables which are the manifestation of climate change.

The study has found that climate change through the increase in the intensity and the frequency of extreme weather events such as episodes of flooding can exacerbate the prevalence of flooding in Fiji. There are minimal effects of droughts and cyclones on the counts of malnutrition due to the strong social protection policies already implemented in Fiji that act as mitigating factors towards the increase in counts of malnutrition. This study has shown the patterns of how individual climate variables and malnutrition classification behave, and how the two variables behave together. The study will lay a platform for a more detailed study of the precise relationship between malnutrition climate change in the future where a Poisson process or a negative binomial regression will be used.

## Chapter 6

# Appendices

### 1 Information Sheet



College of Education, Health Science and Human Development  
Telephone: +64 0211136714  
Email: vakaruru.cavuiliati@pg.canterbury.ac.nz  
Date: 20 July, 2017

**The Director,  
Fiji Meteorological Office,  
Private Mail Bag,  
Nadi Airport**

*Dear Sir,*

Hi, I am Vakaruru Cavuiliati, a civil servant currently on study leave and undertaking a postgraduate study at the University of Canterbury. I'm undertaking a thesis by research on Climate Change and Human Health: An Ecological study on climate variability and malnutrition in Fiji.

The purpose of the research is to determine the relationship between climate variables and the prevalence of malnutrition cases in Fiji. It is an ecological study looking at aggregated health effects of malnutrition from January 2006 to December 2016. The climate variables will be the measurements of average minimum, and maximum relative humidity, temperature and precipitation from January 2006 to December 2016. The data is stored and available from the Fiji Meteorological Service. Malnutrition data which is classified and stored in the Ministry of Health and Medical Services database will be collected for the same period. While variability in the weather can be associated with the prevalence of malnutrition in Fiji, other confounding factors can affect the outcome of the study. These are gender, ethnicity, food security, socioeconomic status, and the availability of water and sanitation. The confounding variables data are to be collected from the various government departments and ministries that have these data in their database. A time series graph will be plotted for the average minimum, maximum temperature, humidity and precipitation from January 2006 to December 2016 to determine if there is a variant or invariant change in Fiji's climate during that period. Statistical modelling will be carried out to determine if there is a relationship between climate variables and malnutrition and the significance of the relationship while accounting for other factors.

The purpose of this letter is to seek your approval to extract the climate data from your organization. I am specifically looking at the minimum, maximum monthly temperature, precipitation and relative humidity for Fiji from January 2006 to December 2016. This would greatly help in the statistical analysis of my study.

The project is being carried out as a Thesis for Masters of Health Sciences (Environment and Health) under the supervision of Dr. Arindam Basu and Professor Steven Ratuva who can be contacted at [arindam.basu@canterbury.ac.nz](mailto:arindam.basu@canterbury.ac.nz) and [steven.ratuva@canterbury.ac.nz](mailto:steven.ratuva@canterbury.ac.nz). They will be pleased to discuss any concerns you may have about participation in the project.

If you have any queries please contact me on my email [vakaruru.cavuiliati@pg.canterbury.ac.nz](mailto:vakaruru.cavuiliati@pg.canterbury.ac.nz).

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Vakaruru'.

Vakaruru Cavuiliati

F-CSD/001



## Fiji Meteorological Service

## Historical Meteorological Data Request Form

## A. Client Information

Name: VAKARURU. CAVULATI

Organisation/Affiliation: UNIVERSITY OF CANTERBURY

Address: 2 HOMESTEAD LANE, ILAM, CHRISTCHURCH 8041, NZ.

Postal Address (if different from the above): \_\_\_\_\_


Phone: (64) 211136714 Fax: \_\_\_\_\_

Email: Vakaruru.Cavilati@pg.canterbury.ac.nz


## B. Purpose of the Request

Provide details of the purpose for this request (attach additional pages if required). If this request is for academic research, then attach a detailed research proposal. Please note that approval of data release is subject to project relevancy.

The purpose of this request is for academic research. Please find the detailed research proposal attached.

<b>C. Details of the data</b>	
Provide details of the data which is required. Be as specific as possible about meteorological variable/s, time resolution, location/s and data period.	
Location:	<u>Fiji</u>
Meteorological Variable:	<u>average maximum temperature, average minimum temperature, average rainfall, average humidity</u>
Time Resolution:	<u>Monthly</u>
Data Period:	<u>January 2006 to December 2016.</u>
Mode of delivery:	
<input type="checkbox"/> Post	<input type="checkbox"/> Fax <input checked="" type="checkbox"/> Email <input type="checkbox"/> Collect
<b>D. Declaration</b>	
I hereby undertake neither to transfer nor to sell for whatever reason whatsoever the data supplied by Fiji Meteorological Service.	
Moreover, if this study is published, I undertake to:	
<ul style="list-style-type: none"> <li>• Acknowledge clearly " FIJI METEOROLOGICAL SERVICE" as having supplied the data in question; and</li> <li>• Supply a copy of the study, once this is finished, to the Fiji Meteorological Service.</li> </ul>	
Signature: <u></u>	Date: <u>26/07/17</u>
Stamp	





**UC**  
UNIVERSITY OF  
CANTERBURY  
*Te Whare Wānanga o Waitaha*  
CHRISTCHURCH NEW ZEALAND

College of Education, Health Science and Human Development  
 Telephone: +64 0211136714  
 Email: vakaruru.cavuilati@pg.canterbury.ac.nz  
 Date: 18 September, 2017

**The Permanent Secretary,  
 Ministry of Agriculture,  
 Private Mail Bag,  
 Suva**

pao (stats)  
 Please facilitate.  
 Inform her.

26/9

26/09.

Dear Sir,


Hi, I am Vakaruru Cavuilati, a civil servant currently on study leave and undertaking a postgraduate study at the University of Canterbury. I'm undertaking a thesis by research on Climate Change and Human Health: An Ecological study on climate variability and malnutrition in Fiji.

The purpose of the research is to determine the relationship between climate variables and the prevalence of malnutrition cases in Fiji. It is an ecological study looking at aggregated health effects of malnutrition from January 2006 to December 2016. The climate variables will be the measurements of average minimum, and maximum relative humidity, temperature and precipitation from January 2006 to December 2016. The data is stored and available from the Fiji Meteorological Service. Malnutrition data which is classified and stored in the Ministry of Health and Medical Services database will be collected for the same period. While variability in the weather can be associated with the prevalence of malnutrition in Fiji, other confounding factors can affect the outcome of the study. These are gender, ethnicity, food security, socioeconomic status, and the availability of water and sanitation. The confounding variables data are to be collected from the various government departments and ministries that have these data in their database. A time series graph will be plotted for the average minimum, maximum temperature, humidity and precipitation from January 2006 to December 2016 to determine if there is a variant or invariant change in Fiji's climate during that period. Statistical modelling will be carried out to determine if there is a relationship between climate variables and malnutrition and the significance of the relationship while accounting for other factors.


The purpose of this letter is to seek your approval to extract the food security data from your organization. I am specifically looking at the agriculture and livestock production for Fiji and the monthly costs of agricultural produce from January 2006 to December 2016. I request if the data could be accessed on a monthly basis for the ten year period. This would greatly help in the statistical analysis of my study. The project is being carried out as a Thesis for Masters of Health Sciences (Environment and Health) under the supervision of Dr. Arindam Basu and Professor Steven Ratuva who can be contacted at [arindam.basu@canterbury.ac.nz](mailto:arindam.basu@canterbury.ac.nz) and [steven.ratuva@canterbury.ac.nz](mailto:steven.ratuva@canterbury.ac.nz). They will be pleased to discuss any concerns you may have about participation in the project

If you have any queries please contact me on my email [vakaruru.cavuilati@pg.canterbury.ac.nz](mailto:vakaruru.cavuilati@pg.canterbury.ac.nz).

Yours sincerely,



Vakaruru Cavuilati



18/9/17

## HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson  
Telephone: +64 03 369 4588, Extn 94588  
Email: [human-ethics@canterbury.ac.nz](mailto:human-ethics@canterbury.ac.nz)



13 September 2017

Vakaruru Cavuilati  
College of Education, Health and Human Development  
University of Canterbury

Dear Vakaruru,

Following on from my email of today's date, I can confirm that the Chair of the Human Ethics Committee, Associate Professor Jane Maidment has reviewed your research proposal titled "*Climate Change and Human Health: An Ecological study on climate variability and malnutrition in Fiji*", and also gives the Human Ethics Committee's approval to the research approved by the Fijian National Health Research and Ethics Review Committee .



## Fiji National Health Research and Ethics Review Committee

Level 2 Dinem House  
88 Amy Street, Toorak.  
Box 2223, Govt. Building  
Suva, Fiji

Phone : (679) 3306177 / 3221 424  
Fax : (679) 3318227  
Email: [rosimina.tubuitamano@govnet.gov.fj](mailto:rosimina.tubuitamano@govnet.gov.fj)  
Website: [www.health.gov.fj](http://www.health.gov.fj)

10<sup>th</sup> August 2017

Vakaruru Cavuilati  
University of Canterbury,  
New Zealand

**Project Title: "Climate Change and Human Health: An Ecological study on climate variability".**

**FNHRERC Number:** 2017.117.NW.  
**Primary Investigator(s):** Vakaruru Cavuilati, UC, NZ  
**Primary-Supervisor(s):** Dr. Arindam Basu, UC, NZ  
Professor Steven Ratuva, UC, NZ

Dear Vakaruru,

This is to inform you that the Fiji National Health Research Ethics Review Committee (FNHRERC) has granted scientific, technical and ethical **approval** to your proposal titled "*Climate Change and Human Health: An Ecological study on climate variability*".

As the Principle Investigator, it is **your responsibility** to ensure that all the people associated with this particular project area aware of the conditions of this approval and copy of the final report is also submitted to the Ministry of Health and Medical Services at the conclusion of your project for our records.

The following conditions apply to your approval. Failure to abide by these conditions may result in suspension or discontinuation of approval and/or disciplinary action.

- Variation to the project:** Any subsequent variation s or modifications you may wish to make to your project must be notified formally to the Chair, FNHRERC for further considerations and approval. If the Chair considers that the proposed changes are significant, you may be required to submit a new application for approval of the revised project.
- Incidence or adverse events:** Researchers must report immediately to the Chair FNHRERC anything which may affect the ethical acceptance of the protocol including adverse effects on subjects or unforeseen events that may affect continued ethical acceptability of the project. Failure to do so may result in suspension or cancellation of approval.
- Monitoring:** Projects are subject to monitoring at any time by the Committee

4. **Annual/Final Report:** You must submit a progress report at 6 months of your study and an annual/final report at the end of the year or at the conclusion of the project if it continues for less than or more than a year. Also you are to present the evidence back to the participating institutions.

Please quote the FNHRERC number and the name of the project in any future correspondence.

If you have any further queries or require any additional information, please do not hesitate to contact the Secretariat on telephone: (679) 3306177 ext. 340170 or email: [rosimina.tubuitamana@govnet.gov.fj](mailto:rosimina.tubuitamana@govnet.gov.fj).

We wish you all the best in your study.



Mr. Shivnay Naidu

Chairperson

Fiji National Health Research Ethics Review Committee

## 2 R Codes

This is the R Code for the climate variables (minimum and maximum temperatures, total rainfall and total relative humidity) time series analysis.

```
library(tidyverse)
library(tseries)
library(forecast)

#{r read_data}

vaks_data = read_csv("Final Dataset 2.csv")

head(vaks_data)
> head(vaks_data)
# A tibble: 6 x 9
      DATE max_temp min_temp total_rainfall min_relative_humidity
  <dtm>   <dbl>   <dbl>         <dbl>             <dbl>
1 2009-01-31    30.7    23.5         822.7             81.3
2 2009-02-28    31.2    23.4         252.6             80.2
3 2009-03-31    31.4    23.6         282.6             82.3
4 2009-04-30    30.4    22.9         192.4             80.4
5 2009-05-31    29.2    22.0         240.4             80.4
6 2009-06-30    27.8    20.7         166.5             76.6
# ... with 4 more variables: underweight <int>, growth_faltering <int>,
#   severe_mal <int>, anemia <int>

#Maximum Temperature
vaks_data$maxtemp = ts(vaks_data$max_temp,
                      start = c(2009, 1),
                      frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, maxtemp)

##seasonal plot for maximum temperature
seasonplot(vaks_ts$maxtemp,
           main = "Seasonal plot for the Maximum Temperature",
           year.labels = TRUE, year.labels.left = TRUE, col = 1:10,
           ylab = "Maximum Temperature",
           ylim = c(0,33))

monthplot(vaks_ts$maxtemp,
          main = "Seasonal deviation plot for monthly average maximum temperature",
          xlab = "Month",
          ylab = "Monthly average maximum temperature")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

##Examination and cleaning of data
```

```

vaks_ts$smoothed_mt = tsclean(vaks_ts$maxtemp)

##Step Two
## Smoothing
vaks_ts$smoothed_mt = ma(vaks_ts$smoothed_mt, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_mt), colour = "blue")

##Step Three
##Decomposition
decomposed_mxraw = stl(vaks_ts$maxtemp, s.window = "periodic")

decomposed_raw = decompose(vaks_ts$maxtemp)
vaks_ts$decomposed_mx = decomposed_raw$trend

## Plotting the time series of maximum temperature,
the smoothing using the simple moving average and the trend after decomposing.

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = maxtemp), colour = "red1") +
  geom_line(aes(x = DATE, y = smoothed_mt), colour = "springgreen4") +
  geom_line(aes(x = DATE, y = decomposed_mx), colour = "blue") +
  theme_bw() + ylim(0,33) + ylab("Maximum Temperature") + xlab("Time") +
  ggtitle("Maximum Temperature Time Series, Smoothing and Decomposition")

## Plotting the minimum temperature trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposed_mx), colour = "blue") +
  theme_bw() + ylim(0,33) + ylab("Maximum Temperature") +
  xlab("Time") + ggtitle("Trend of Maximum Temperature")

##Minimum Temperature Variable
Converting the dataset to time series
vaks_data$min_temp = ts(vaks_data$min_temp,
                        start = c(2009,1),
                        frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, min_temp)

#Plotting the seasonal plot for minimum temperature
season_plot(vaks_ts$min_temp,
            main = "Seasonal plot for the Minimum Temperature",
            year.labels = TRUE, year.labels.left = TRUE, col = 1:10,
            ylab = "Minimum Temperature")

##Examination and cleaning of data
vaks_ts$smoothed_mint = tsclean(vaks_ts$min_temp)

```

```

##Step Two
## Smoothing
vaks_ts$smoothed_mint = ma(vaks_ts$smoothed_mint, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_mint), colour = "blue")

##Step Three
##Decomposition of the series
decomposed_mintraw = stl(vaks_ts$min_temp, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$min_temp)
vaks_ts$decomposemint = decomposed_raw$trend

# Plotting the time series, the smoothing and the trend
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = min_temp), colour = "red1") +
  geom_line(aes(x = DATE, y = smoothed_mint), colour = "springgreen4") +
  geom_line(aes(x = DATE, y = decomposemint), colour = "blue") +
  theme_bw() + ylim(0,25) + ylab("Minimum Temperature") + xlab("Time") +
  ggtitle("Minimum Temperature Time Series, Smoothing and Decomposition")

# Plotting the trend after smoothing and decomposing the series
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposemint), colour = "blue") +
  theme_bw() + ylim(0,25) + ylab("Minimum Temperature") +
  xlab("Time") + ggtitle("Trend of Minimum Temperature")

##Total Rainfall Series
## The dataset is converted to a time series
vaks_data$total_rainfall = ts(vaks_data$total_rainfall,
                             start = c(2009,1),
                             frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, total_rainfall)

# Constructing the seasonal Plot to determine the seasonality of the series
seasonplot(vaks_ts$total_rainfall,
           main = "Seasonal plot for the Total Rainfall",
           year.labels = TRUE, year.labels.left = TRUE,
           col = 1:10, ylab = "Total Rainfall",
           ylim = c(0,900))

monthplot(vaks_ts$total_rainfall,
          main = "Seasonal deviation plot for Growth Faltering counts",
          xlab = "Month",
          ylab = "Count of growth faltering population")

```

```

axis(1, at=1:12, labels = month.abb, cex = 0.8)

##Examination and cleaning of data
vaks_ts$smoothed_train = tsclean(vaks_ts$total_rainfall)

##Step Two
## Smoothing using the simple moving average
vaks_ts$smoothed_train = ma(vaks_ts$smoothed_train, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_train), colour = "blue")

##Step Three
##Decomposition of the series
decomposed_train = stl(vaks_ts$total_rainfall, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$total_rainfall)
vaks_ts$decomposerain = decomposed_raw$trend

#Plotting the series, the smoothing and the trend
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = total_rainfall), colour = "red1") +
  geom_line(aes(x = DATE, y = smoothed_train), colour = "springgreen4") +
  geom_line(aes(x = DATE, y = decomposerain), colour = "blue") +
  theme_bw() + ylim(0,900) + ylab("Total Rainfall") + xlab("Time") +
  ggtitle("Total Rainfall Time Series, Smoothing and Decomposition")

## Plotting the trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposerain), colour = "blue") +
  theme_bw() + ylim(0,300) + ylab("Total Rainfall") +
  xlab("Time") + ggtitle("Trend of Total Rainfall")

## Relative Humidity
## Converting the dataset to a time series
vaks_data$min_relative_humidity = ts(vaks_data$min_relative_humidity,
                                     start = c(2009,1),
                                     frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, min_relative_humidity)

#Plotting a seasonal plot to determine seasonality
seasonplot(vaks_ts$min_relative_humidity,
            main = "Seasonal plot for the Relative Humidity",
            year.labels = TRUE, year.labels.left = TRUE,
            col = 1:10, ylab = "Total Relative Humidity",
            ylim = c(0,90))

monthplot(vaks_ts$min_relative_humidity,

```



```

    main = "Seasonal deviation plot for humidity counts",
    xlab = "Month",
    ylab = "Relative Humidity percentage")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

##Examination and cleaning of data
vaks_ts$smoothed_hum = tsclean(vaks_ts$min_relative_humidity)

##Step Two
## Smoothing using the moving average
vaks_ts$smoothed_hum = ma(vaks_ts$smoothed_hum, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_hum), colour = "blue")

##Step Three
##Decomposition
decomposed_hum = stl(vaks_ts$min_relative_humidity, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$min_relative_humidity)
vaks_ts$decomposehum = decomposed_raw$trend

## Plotting the time series, the smoothing and the decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = min_relative_humidity), colour = "red1") +
  geom_line(aes(x = DATE, y = smoothed_hum), colour = "springgreen4") +
  geom_line(aes(x = DATE, y = decomposehum), colour = "blue") +
  theme_bw() + ylim(0,85) + ylab("Relative Humidity") + xlab("Time") +
  ggtitle("Humidity Time Series, Smoothing and Decomposition")

#Plotting the trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposehum), colour = "blue") +
  theme_bw() + ylim(0,85) + ylab("Relative Humidity") +
  xlab("Time") + ggtitle("Trend of Relative Humidity")

The following R Codes is for the malnutrition classification (underweight, growth faltering, severe
malnutrition & anaemia) time series.

## Coverting the Underweight dataset to time series
vaks_data$uweight = ts(vaks_data$underweight,
                      start = c(2009, 1),
                      frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, uweight, max_temp)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = uweight))

```

```
##breaking the series into two, one before 2013 and the other after 2013
to determine how the series behaves during these two periods.
```

```
library(lubridate)
vaks_data_pre_post = vaks_data %>%
  mutate(year = year(ymd(DATE)),
         pre_2013 = (year > 2013)
  )

ggplot(vaks_data_pre_post) +
  geom_line(aes(x = DATE, y = uweight)) +
  facet_wrap(~pre_2013) + ylab("Counts of Underweight") +
  xlab("Time") + ggtitle("Underweight Counts before and after 2013")

##Examination and cleaning of data
vaks_ts$smoothed_wt = tsclean(vaks_ts$uweight)

#Plotting seasonality for underweight
seasonplot(vaks_ts$uweight,
  main = "Seasonal plot for the Underweight",
  year.labels = TRUE, year.labels.left = TRUE, col = 1:10, ylab = "Count",
  ylim = c(0,750))

monthplot(vaks_ts$uweight,
  main = "Seasonal deviation plot for underweight counts",
  xlab = "Month",
  ylab = "Count of underweight population")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

## Smoothing using the moving average
vaks_ts$smoothed_wt = ma(vaks_ts$smoothed_wt, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_wt), colour = "blue")

##Decomposition, calculating for seasonal component
decomposed_uwraw = stl(vaks_ts$uweight, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$uweight)
vaks_ts$decomposed_uw = decomposed_raw$trend

##Plotting the series, the smoothing and the trend
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = uweight), colour = "red") +
  geom_line(aes(x = DATE, y = smoothed_wt), colour = "green") +
  geom_line(aes(x = DATE, y = decomposed_uw), colour = "blue") +
  theme_bw() + ylab("Counts of Underweight") + xlab("Time") +
  ggtitle("Underweight Timeseries, Smoothing and Decomposition")

## plotting the trend after smoothing and decomposition
```

```

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposed_uw), colour = "blue") +
  theme_bw() + ylim(0,500) +
  ylab("Counts of Underweight") + xlab("Time") +
  ggtitle("Trend of Underweight")

###De-sensationalising the series
decomposed_uwraw = stl(vaks_ts$uweight, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$uweight)
vaks_ts$decomposed_uw = decomposed_raw$seasonal

###deseasoning the time series
ts.stl <- stl(vaks_ts$decomposed_uw, "periodic")
ts.sa <- seasadj(ts.stl)
plot(vaks_ts$decomposed_uw, type = "l",
      ylab = "Underweight", main = "Seasonal Time Series of Underweight")
plot(ts.sa, type = "l",
      ylab = "Underweight", main = "De-Seasonalised Series of Underweight")
seasonplot(ts.sa, 12, col = rainbow(12),
            ylab = "Underweight", xlab = "Months",
            main = "De-Seasonalised Series of Underweight")

## Autocorrelation and choosing order model
Acf(vaks_ts$uweight)
pacf(vaks_ts$uweight)

#Testing for stationarity
adf.test(vaks_ts$uweight, alternative = "stationary")

###Growth Faltering dataset
vaks_data$growth_faltering = ts(vaks_data$growth_faltering,
                                start = c(2009,1),
                                frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, growth_faltering)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = growth_faltering))

#separating the series to determine the patters before 2013 and after 2013
library(lubridate)
vaks_data_pre_post = vaks_data %>%
  mutate(year = year(ymd(DATE)),
         pre_2013 = (year > 2013)
  )

ggplot(vaks_data_pre_post) +

```

```

geom_line(aes(x = DATE, y = growth_faltering)) +
facet_wrap(~pre_2013 ) + ylab("Counts of Growth Faltering") +
xlab("Time") + ggtitle("Growth Faltering Counts before and after 2013")

##Examination and cleaning of data
vaks_ts$smoothed_gf = tsclean(vaks_ts$growth_faltering)

#determining the seasonality of growth faltering
seasonplot(vaks_ts$growth_faltering ,
            main = "Seasonal plot for Growth Faltering",
            year.labels = TRUE, year.labels.left = TRUE, col = 1:10, ylab = " Count",
            ylim = c(0,200))

monthplot(vaks_ts$growth_faltering ,
           main = "Seasonal deviation plot for Growth Faltering counts",
           xlab = "Month",
           ylab = "Count of growth faltering population")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

## Smoothing
vaks_ts$smoothed_gf = ma(vaks_ts$smoothed_gf, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_gf), colour = "blue")

##Decomposition of the series
decomposed_gfraw = stl(vaks_ts$growth_faltering, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$growth_faltering)
vaks_ts$decomposed_gf = decomposed_raw$trend

# Plotting the series , the smoothing and the trend
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = growth_faltering), colour = "red") +
  geom_line(aes(x = DATE, y = smoothed_gf), colour = "green4") +
  geom_line(aes(x = DATE, y = decomposed_gf), colour = "blue") +
  theme_bw() + ylab("Counts of Growth Faltering") + xlab("Time") +
  ggtitle("Growth Faltering Timeseries, Smoothing and Decomposition") +
  ylim(0,180)

## plotting the trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposed_gf), colour = "blue") +
  theme_bw() + ylim(0,100) +
  ylab(" Counts of Growth Faltering") + xlab("Time") +
  ggtitle("Trend of Growth Faltering")

## De seasoning the growth faltering series
decomposed_raw = decompose(vaks_ts$growth_faltering)
vaks_ts$decomposed_gf = decomposed_raw$seasonal

```

```

ts.stl <- stl(vaks_ts$decomposed_gf, "periodic")
ts.sa <- seasadj(ts.stl)
plot (vaks_ts$decomposed_gf, type = "l")
plot (ts.sa, type = "l")
seasonplot(ts.sa,12, col = rainbow(12),
ylab = "Growth Faltering", xlab = "Months", main = "De-Seasonalised Series of Growth Fa

## Autocorrelation and choosing order model
Acf(vaks_ts$growth_faltering)
pacf(vaks_ts$growth_faltering)

Testing for stationary
adf.test(vaks_ts$growth_faltering, alternative = "stationary")

##Severe Malnutrition dataset
Converting the dataset to time series
vaks_data$severe_mal = ts(vaks_data$severe_mal,
                          start = c(2009,1),
                          frequency = 12)

vaks_ts = vaks_data %>%
  select (DATE, severe_mal)

ggplot(vaks_ts) +
  geom_line(aes( x = DATE, y = severe_mal))

library(lubridate)
vaks_data_pre_post = vaks_data %>%
  mutate(year = year(ymd(DATE)),
         pre_2013 = (year > 2013)
  )

ggplot(vaks_data_pre_post) +
  geom_line(aes(x = DATE, y = severe_mal)) +
  facet_wrap(~pre_2013 ) + ylab("Counts of Severe Malnutrtion") +
  xlab("Time") + ggtitle("Severe Malnutrition Counts before and after 2013")

##Examination and cleaning of data
vaks_ts$smoothed_svm = tsclean(vaks_ts$severe_mal)

## Plotting the seasonality of severe malnutrition
seasonplot(vaks_ts$severe_mal,
           main = "Seasonal plot for Severe Malnutrition",
           year.labels = TRUE, year.labels.left = TRUE, col = 1:10, ylab = " Counts of C
           ylim = c(0,80))

monthplot(vaks_ts$severe_mal,

```

```

        main = "Seasonal deviation plot for Severe Malnutrition counts",
        xlab = "Month",
        ylab = "Count of severe malnutrition population")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

## Smoothing
vaks_ts$smoothed_svm = ma(vaks_ts$smoothed_svm, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_svm), colour = "blue")

##Decomposition
decomposed_svmraw = stl(vaks_ts$severe_mal, s.window = "periodic")
decomposed_raw = decompose(vaks_ts$severe_mal)
vaks_ts$decomposed_svm = decomposed_raw$trend

## plotting the trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = severe_mal), colour = "red") +
  geom_line(aes(x = DATE, y = smoothed_svm), colour = "green4") +
  geom_line(aes(x = DATE, y = decomposed_svm), colour = "blue") +
  theme_bw() + ylab("Counts of Severe Malnutrition") + xlab("Time") +
  ggtitle("Severe Malnutrition Timeseries, Smoothing and Decomposition") +
  ylim(0,75)

#Plotting the trend after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposed_svm), colour = "blue") +
  theme_bw() + ylim(0,40) +
  ylab("Counts of Severe Malnutrition") + xlab("Time") +
  ggtitle("Trend of Severe Malnutrition")

De sensationalising the series
decomposed_raw = decompose(vaks_ts$severe_mal)
vaks_ts$decomposed_svm = decomposed_raw$seasonal
##De seasoning
ts.stl <- stl(vaks_ts$decomposed_svm, "periodic")
ts.sa <- seasadj(ts.stl)
plot(vaks_ts$decomposed_svm, type = "l")
plot(ts.sa, type = "l")
seasonplot(ts.sa, 12, col = rainbow(12),
           ylab = "Severe Malnutrition",
           xlab = "Months",
           main = "De-Seasonalised Series of Severe Malnutrition")

## Autocorrelation and choosing order model
Acf(vaks_ts$severe_mal)
pacf(vaks_ts$severe_mal)

```

```

#Testing for stationary of the series
adf.test(vaks_ts$severe_mal, alternative = "stationary")

##Anaemia
vaks_data$anemia = ts(vaks_data$anemia,
                      start = c(2009,1),
                      frequency = 12)

vaks_ts = vaks_data %>%
  select(DATE, anemia)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = anemia))

library(lubridate)
vaks_data_pre_post = vaks_data %>%
  mutate(year = year(ymd(DATE)),
         pre_2013 = (year > 2013)
  )

ggplot(vaks_data_pre_post) +
  geom_line(aes(x = DATE, y = anemia)) +
  facet_wrap(~pre_2013) + ylab("Counts of Anemia") +
  xlab("Time") + ggtitle("Anemia Counts before and after 2013")

##Examination and cleaning of data
vaks_ts$smoothed_an = tsclean(vaks_ts$anemia)

#Seasonality of anaemia
seasonplot(vaks_ts$anemia,
           main = "Seasonal plot for Anaemia",
           year.labels = TRUE, year.labels.left = TRUE, col = 1:10, ylab = "Counts of A",
           ylim = c(0,80))

monthplot(vaks_ts$anemia,
          main = "Seasonal deviation plot for Anaemia counts",
          xlab = "Month",
          ylab = "Count of anaemia population")
axis(1, at=1:12, labels = month.abb, cex = 0.8)

## Smoothing
vaks_ts$smoothed_an = ma(vaks_ts$smoothed_an, order = 6)

ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = smoothed_an), colour = "blue")

##Decomposition
decomposed_anraw = stl(vaks_ts$anemia, s.window = "periodic")

```

```

decomposed_raw = decompose(vaks_ts$anemia)
vaks_ts$decomposed_an = decomposed_raw$trend

# Time series , smoothing using moving average and trend
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = anemia), colour = "red") +
  geom_line(aes(x = DATE, y = smoothed_an), colour = "green4") +
  geom_line(aes(x = DATE, y = decomposed_an), colour = "blue") +
  theme_bw() + ylab("Counts of Anaemia") + xlab("Time") +
  ggtitle("Anaemia Timeseries , Smoothing and Decomposition") +
  ylim(0,75)

# trend of anaemia after smoothing and decomposition
ggplot(vaks_ts) +
  geom_line(aes(x = DATE, y = decomposed_an), colour = "blue") +
  theme_bw() + ylim(0,40) +
  ylab("Counts of Anaemia") + xlab("Time") +
  ggtitle("Trend of Anaemia")

# de seasoning the series
decomposed_raw = decompose(vaks_ts$anemia)
vaks_ts$decomposed_an = decomposed_raw$seasonal
ts.stl <- stl(vaks_ts$decomposed_an, "periodic")
ts.sa <- seasadj(ts.stl)
plot (vaks_ts$decomposed_an, type = "l")
plot (ts.sa, type = "l")
seasonplot(ts.sa,12, col = rainbow(12),
           ylab = "Anaemia",
           xlab = "Months",
           main = "De-Seasonalised Series of Anaemia")

## Autocorrelation and choosing order model
Acf(vaks_ts$anemia)
pacf(vaks_ts$anemia)

# Test for stationarity
adf.test(vaks_ts$anemia, alternative = "stationary")

```

The following R Codes are used to determine the trend and the patterns of crop productions in Fiji

```

Crop Production Analysis
library(tidyverse)
library(dbplyr)
library(tidyr)
library(ggplot2)
library(reshape2)
library(ggrepel)
library(scales)
library(tseries)

```



```
library(xts)
library(lubridate)
library(fpp2)
library(zoo)
library(seasonal)
library(ggseas)

# Read the dataset into the R
mydata <- read_csv("crops_final.csv")

##Generating a barplot for quarterly crop production from 2009 –2016

ggplot(mydata, aes(x = years, y = production, fill = quarters)) +
  geom_bar(position = "dodge", stat = "identity") +
  xlab("Years") + ylab("Crop Production in Tonnes") +
  ggtitle("Quarterly Crop Production in Fiji (2009 – 2016)") +
  scale_x_continuous(breaks = seq(2009,2016)) +
  geom_text(aes(label=quarters),position = position_dodge(width = 0.9),vjust = 1)

##Determining the trend of crop production

## Constructing the time series for crop production
p1 <- ts(mydata)
p1 <- ts(mydata, frequency = 4, start = c(2009,4))
plot.ts(mydata, ylab = "Crop Production in Tonnes", main = "Time Series Graph of
      Crop Production")

# Simple moving average used to determine the trend.

trend_max = ma(p1, order = 4, centre = T)
autoplot(as.ts(p1))
lines(trend_max)
autoplot(as.ts(trend_max), ylab = "Crop Production in Tonnes",
  main = "Trend of Crop Production from 2009 to 2016",
  ylim = c(0,80000),
  cex.main = 0.9, cex.lab = 0.5, cex.axis = 0.5)
```

## Raw Dataset

		ROTUMA DATA							
DATE		mn_max_	mn_min_air_	tot_rain	mn_rel_humidity				
2006-01	Calc	30.7	24.6	954.1	83.4				
2006-02	Calc	30.1	24.8	401.2	86				
2006-03	Calc	31.3	25.3	223.9	83.3				
2006-04	Calc	31.8	25.3	89.5	77.4				
2006-05	Calc	31.1	24.8	321.9	84.9				
2006-06	Calc	29.9	25.1	400.4	86.1				
2006-07	Calc	29	24	189.7	80.9				
2006-08	Calc	29.7	24.5	182.6	79.5				
2006-09	Calc	29.7	24.5	220.6	85.4				
2006-10	Calc	30.3	24.8	486.3	85.6				
2006-11	Calc	30.4	25	456.7	84.9				
2006-12	Calc	31	24.9	446.6	83				
2007-01	Calc	32.1	25.3	192.5	79.5				
2007-02	Calc	30.4	25.1	433	85.1				
2007-03	Calc	29.9	24.6	523.7	85.3				
2007-04	Calc	30.9	25	300.2	83.6				
2007-05	Calc	30.8	24.5	326.3	84.2				
2007-06	Calc	30.8	24.8	116.7	84.5				
2007-07	Calc	30.5	24.8	207.2	83.5				
2007-08	Calc	30.2	24.8	361.8	85				
2007-09	Calc	30.6	24.9	157.3	82.1				
2007-10	Calc	30.6	24.6	369	82.4				
2007-11	Calc	30.3	24.4	435.7	77.9				
2007-12	Calc	31.3	25	236.4	80.9				
2008-01	Calc	29.8	24.1	448.8	86.7				
2008-02	Calc	31.2	25	163.9	82.5				
2008-03	Calc	31.2	24.5	173.2	80.8				
2008-04	Calc	31.2	24.6	273.4	78.5				
2008-05	Calc	30.2	24.2	522.5	81.3				
2008-06	Calc	30.1	24.1	374.3	81.4				
2008-07	Calc	29.2	24.4	453.3	79.2				
2008-08	Calc	29.8	24.7	235.7	78.9				
►	Ba	Labasa	Lakeba	Laucala	Nadi	Nausori	Ono-I-Lau	Savusavu	Rotuma

Figure 6.1: The raw climate variables dataset as provided by the Fiji Meteriological Service, it contained the aveaged monthly data from the nine weather stations in Fiji

### 2.1 Malnutrition Data Sorting

The dataset for 2009, the spreadsheet had on each sheets the different divisions where the data was collected. The data was stored in a table format where the header had the reporting period, the sub division, the facility, the number seen at the IMCI, the ethnicity and the classification of malnutrition (severe malnutrition, severe anaemia, anaemia, low weight, growth faltering). The

Mildly Under Weight 75-89%						Moderately Under Weight 60-74%						Severely Under Weight <60%					
0 < 1 yr			1 - 4 yrs			0 < 1 yr			1 - 4 yrs			0 < 1 yr			1 - 4		
Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	35	2	6	20	0	3	2	0	1	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6.2: The raw malnutrition dataset from January 2006 to December 2006 as issued by the Ministry of Health & Medical Services Fiji. The malnutrition is classified as mild, moderate and severe underweight

Reporting Period	Facility	IMCI No Soon			Malnutrition & Anaemia														
		Severe Malnutrition			Severe Anaemia			Anaemia			Low Weight			Growth Faltering					
		Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth	Fij	Ind	Oth
ANUARY	BA GOPD&SOPD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA HC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA MCH	0	0	0	1	6	0	0	0	0	0	0	0	8	12	0	2	4	0
ANUARY	BA NAVATU ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA RARAWAI ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA SOROKABA ZN	3	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA VAROKA ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA VATULALAU ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA VEISARU ZN	24	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BA WAILALAI ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BAGASAU NS	9	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ANUARY	BALEVUTO CN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BALEVUTO MOTO ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BALEVUTO NUKULOA ZN	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BATIKI NS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BEQA CN	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BEQA DN	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BEQA HC	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	BOUMA NS	86	1	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0
ANUARY	BUA NS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	CIKOBIA NS	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	COQELOA NS	42	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	CUVU MALOMALO ZN2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	CUVU ZN1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
ANUARY	DAWASAMU NS	53	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
ANUARY	DOGOTUKI NS	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
ANUARY	DREKETI ZN 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	DREKETI ZN 2	12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	GALOA NS	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANUARY	KEMALALA ZN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6.3: The raw malnutrition dataset issued by the Ministry of Health & Medical Services from January 2009 to December 2009

sheet for each divisions had all the months, the breakdown of malnutrition into ethnicity and

Hospital filter key : ... - All, Yes - Hospital, No - Health Centres

IMCI 2 mths - 5 yrs, Tabular Report, January 2014 to January 2014

Division	Sub Division	Medical Area	Ethnicity	Malnutrition Anaemia			
				Severe Malnutrition	Anaemia	Low Weight	Growth Faltering
<b>All</b>				<b>11</b>	<b>24</b>	<b>271</b>	<b>62</b>
<b>Central</b>				<b>6</b>	<b>16</b>	<b>146</b>	<b>46</b>
	<i>Naitasiri</i>			0	0	22	0
		<i>Laselevu</i>		0	0	4	0
			<i>iTaukei</i>	0	0	4	0
			<i>Fiji Indians</i>	0	0	0	0
			<i>Others</i>	0	0	0	0
		<i>Nakorosule</i>		0	0	0	0
			<i>iTaukei</i>	0	0	0	0
			<i>Fiji Indians</i>	0	0	0	0
			<i>Others</i>	0	0	0	0
		<i>Naqali</i>		0	0	0	0
			<i>iTaukei</i>	0	0	0	0
			<i>Fiji Indians</i>	0	0	0	0
			<i>Others</i>	0	0	0	0
		<i>Vunidawa</i>		0	0	18	0
			<i>iTaukei</i>	0	0	18	0
			<i>Fiji Indians</i>	0	0	0	0
			<i>Others</i>	0	0	0	0
	<i>Rewa</i>			5	11	77	18
		<i>Mokani</i>		0	0	9	0
			<i>iTaukei</i>	0	0	9	0
			<i>Fiji Indians</i>	0	0	0	0
			<i>Others</i>	0	0	0	0
		<i>Nausori</i>		3	7	42	7
			<i>iTaukei</i>	1	3	18	3
			<i>Fiji Indians</i>	2	4	24	4
			<i>Others</i>	0	0	0	0
		<i>Wainibokasi</i>		2	4	26	11
			<i>iTaukei</i>	2	4	26	11
			<i>Fiji Indians</i>	0	0	0	0

< >
 **january**
 february
 march
 april
 may
 june
 july
 august
 september
 october
 november

classification. Next, the two dataset files for 2010 and 2011 had a single sheet in each of the files that contained a table with a header that had the reporting period, the sub division, the facility, the number seen at the IMCI, the number seen at the IMCI, the ethnicity and the classification of malnutrition ((severe malnutrition, severe anaemia, anaemia, low weight, growth faltering). The dataset had everything in the same sheet from the months, the facility, ethnicity and the classification of malnutrition. The dataset for 2013 to 2016 also had the years stored in single files but the spreadsheet had the months when the data was collected. It was stored in a table form where the header contained the division, the sub division, the medical area, the ethnicity, and the classifications of malnutrition (severe malnutrition, anaemia, low weight, growth faltering). The malnutrition dataset was not stored on its own, it was stored with other infections affecting children such as respiratory, diarrhoea, ear and skin. The Ministry of Health Information Unit Officers Ms. Miriama Rokovutaro and Rosimina Tubuitamana extracted the malnutrition dataset directly from this into a spreadsheet and handed over to the researcher. According to the two officers the malnutrition dataset they have issued are the all the malnutrition data that is available with them. Therefore it is assumed that the malnutrition data entered into the PHIS includes

reports from the Nutrition Monthly Return Register, Malnutrition Admission Register Book, IMCI, GOPD and admissions.

### 3 Figures

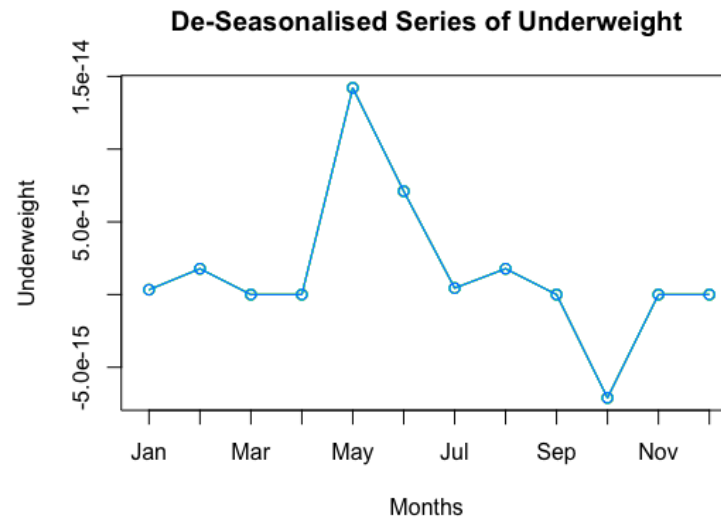


Figure 6.4: *De seasonalising the underweight series*

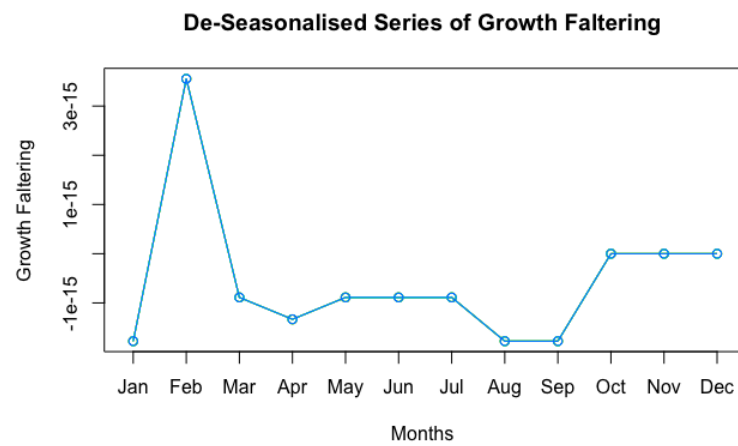


Figure 6.5: *De seasonalising the growth faltering series*

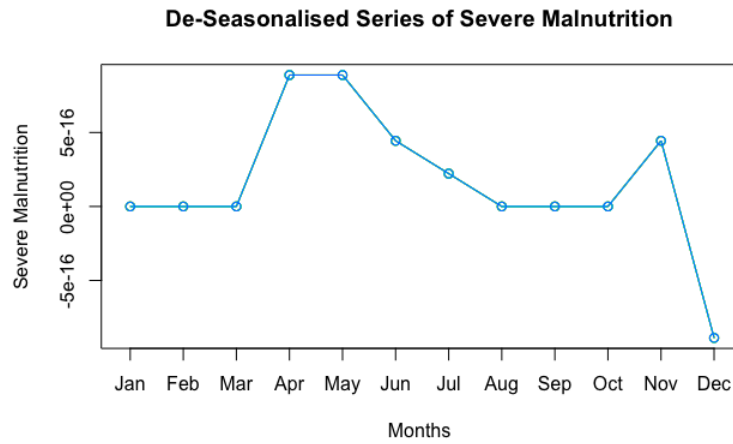


Figure 6.6: *De seasonalising the severe malnutrition series*

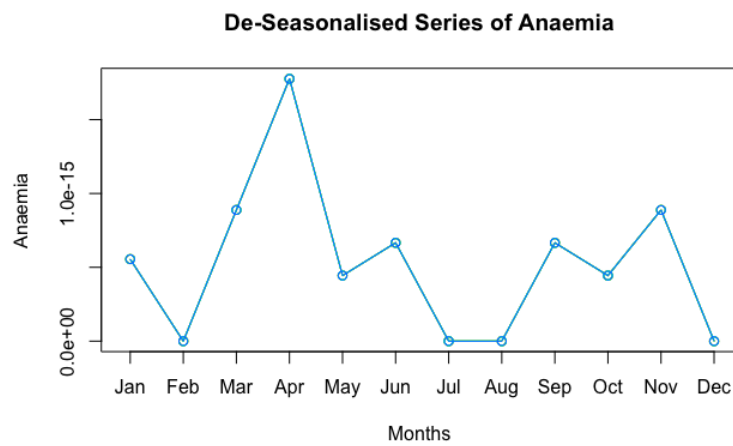


Figure 6.7: *De seasonalising the anaemia series*

**Table 6.1: Government Assistance for Poverty Alleviation: 2014 – 2015 (\$M)**

	2014(R)	2015(B)
<b>Social Welfare</b>		
Poverty Benefit Scheme	22.0	22.0
Child Protection Allowance	4.5	2.0
Social Pension Scheme	3.0	8.0
Food Voucher Programme	1.3	1.0
Women's Plan of Action	0.8	1.0
Integrated National Poverty Eradication Programme	0.3	0.3
Welfare Graduation Program	0.5	0.5
Fiji National Council of Disabled Persons	0.3	0.3
Capital Grant to Voluntary Organizations	0.2	0.2
Women's Resources Centre	0.2	0.0
Grant to Girls' Home	0.1	0.1
Fire Victims Relief	0.1	1.1
<b>Education</b>		
Bus Fare Subsidy	20.8	20.0
<b>Health</b>		
Free Medicine	-	8.0
<b>Department of Housing</b>		
Housing Assistance for First Time Home Buyers	10.0	10.0
Lagilagi Housing Development Project- Phase 2	3.0	2.0
PRB –Savusavu Development Project	2.5	3.4
Squatter Upgrading & Resettlement Programme	2.0	3.0
PRB –Kalabu Development Project	1.5	0.7
HART	1.0	0.5
HA Social Housing Policy	1.0	0.5
Informal Settlement Project	1.0	3.0
Sustainable Income Generating Project	0.7	0.5
City Wide Squatter Upgrading Project	0.5	0.5
National Housing Policy Implementation Plan	0.2	0.2
<b>Prime Minister's Office</b>		
Funds for the Education of Needy Children	0.2	0.2
<b>Strategic Planning</b>		
Northern Development Programme	1.5	1.5

Figure 6.8: *Government social support programs for 2015, from the National Budget Address 2015*



## FIJI CHILD HEALTH RECORD

*This is your child's health record, you must take care of it and present it at every health clinic visit.*

Child's name: \_\_\_\_\_


Child's NHN: \_\_\_\_\_ Mother's Name: \_\_\_\_\_

Mother's NHN number: \_\_\_\_\_ Father's Name: \_\_\_\_\_

Phone [mobile]: \_\_\_\_\_ Phone [land line]: \_\_\_\_\_

Child's Home Address: \_\_\_\_\_

MCH Number: \_\_\_\_\_



**MINISTRY of Health**  
Shaping Fiji's Health

Nearest MCH Clinic:

First MCH Clinic Date:

GIRLS

Figure 6.9: *Fiji Child Health Record Information Section*



Figure 6.10: *Danger Signs that mothers should take the baby for medical attention*

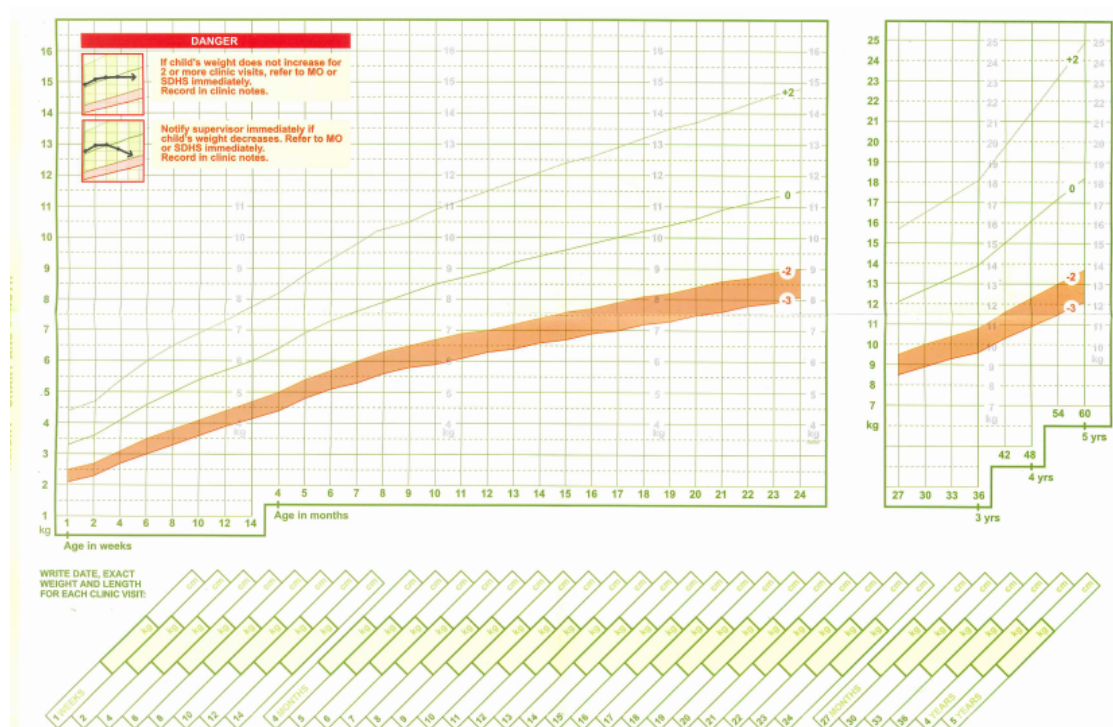


Figure 6.11: The weight and length chart that is used to determine the malnutrition status of the baby



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